ASPECTS OF THE ECOLOGY AND ZOOGEOGRAPHY OF FISHES FROM SOFT-BOTTOM HABITATS OF THE TASMANIAN SHORE ZONE.

BY

PETER R. LAST B.Sc. (Hons.)

University of Tasmania

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Zoology Department,
University of Tasmania,
Hobart.

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Except as stated herein, this thesis contains no material which has been submitted for the award of any other degree or diploma in any University and to the best of my knowledge, contains no paraphrase of material which has previously been written or published by any other person, except where due reference is made in the text of the thesis.

P. R. Last

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ABSTRACT

The fish faunas of the shore zone of coastal lakes, estuaries and beaches of Tasmania were sampled seasonally over a two year period. Environmental characteristics of this zone were described and a classification of habitats was proposed. Three broadly defined soft bottom environments were identified. The first, a closed and semi-closed estuarine environment, contained a complex of habitats including coastal lakes, bar-dammed lagoons and rivers and beach-dammed lagoons. A second type of environment consisted of a range of estuarine systems, such as open lagoons, bay estuaries, tidal rivers and tidal creeks, that are permanently open to the sea. Beach habitats comprised the final environment type and these varied in their exposure to wave action from sheltered to exposed. In general, most habitat types were found to be geographically variable and highly complex which stemmed mainly from regionally differing climatic factors, tidal regimes and degrees of wave exposure.

Soft-bottom habitats did not represent clearly defined biotopes for fish. Instead the 125 species collected in daytime samples were assembled into 4 community types: a coastal freshwater assemblage; an estuarine assemblage; a sheltered beach assemblage; and an exposed beach assemblage. Some species occurred in more than one of these and 7 species were ubiquitous to all four. Compositional variations within each community type and their interactions with changes in substrate, tidal state and salinity were also examined.

The community structures and habitat usages of fishes from two estuaries were examined in detail.

Fishes living over a sandflat in the Derwent Estuary exhibited diel and seasonal changes in abundance and diversity. More species and individuals

and larger fish occurred on the beach at night than during the day. Juveniles of several offshore species were also present within the fauna at night and their occurrences were probably jointly related to the closeness of the sampling site to deep water and a predator evasion response. Seasonal changes in species composition were evident and these were better demonstrated through the use of multivariate analyses than by diversity indices. The 50 fish species sampled, of which 56% were benthopelagic, 40% were benthic and 4% were pelagic, exhibited a high degree of family diversity. More than half of these species were resident in this habitat throughout the year, although some diel transients occurred only on the sandflat in the night or during the day. Seasonal transients consisted of fresh/brackish water invaders during winter and spring and marine invaders during summer and autumn. Transients consisted of several marine species and a few estuarine, migratory euryhaline freshwater and anadromous species.

The distributions and habitat usages of the Great Swanport Estuary and adjacent marine beach by 54 fish species were also investigated during a 2 year sampling programme. Environmental characteristics of the estuary were also studied in detail. Fish were sampled monthly at 7 sites which extended from the semi-exposed beach adjacent to the estuary to a brackish part of the upper estuary. Three assemblages were recognised: a beach assemblage; a lower estuary assemblage; and a middle and upper estuary assemblage. Aspects of reproduction, size structure and trophic relationships of species in these assemblages are discussed. Ten of the 17 major species appeared to spawn in estuaries whilst only one species spawned off the beach. The main spawning period was late spring - early summer and was followed by an influx of juveniles into the estuary during summer and autumn. Most fishes were opportunistic feeders but amphipods were the major prey items consumed.

A checklist is provided for the 216 fish species, more than a third of the fishes occurring in the Tasmanian region, that have been recorded from Tasmanian estuaries. Apart from 12 estuarine species, 9 diadromous species and 4 euryhaline freshwater species, this fauna consists of coastal marine fishes which venture into estuaries with dramatically varying degrees of penetration and frequencies of occurrences. The freshwater component in estuaries, which was shown to be large in the classical curve of Remane, was an insignificant part of the fauna in Tasmanian estuaries.

About three-quarters of the Tasmanian estuarine fish fauna is endemic to Australian waters. A Maugean element is dominant within the the fauna although relationships to Flindersian, Peronian and New Zealand faunas are evident. Antarctic and tropical elements are poorly represented. At the family level, the Tasmanian estuarine fauna exhibits a close association with other temperate regions of the Southern Hemisphere. Temperate estuarine fish faunas of Northern and Southern Hemispheres are distinct whilst those in the North Pacific differ from those of the North Atlantic.

Tasmanian estuaries and sheltered bays are nurseries for several fishes, however, unlike the situation in most other temperate regions, few adult commercial species live in these habitats. Current legislation relating to the management of fish resources in local estuaries is inappropriate and requires a rationalistic review.

CONTENTS

CHAPTER 1

General Introduction

The group of islands forming the Tasmanian region have a coastline approximately 5,300 km long and comprise the most southerly land masses on the Australian continental shelf. The coastal strip, which is a place of considerable climatic and physiographic variation, is also complex ecologically (Goldin, 1980). These features make the region particularly interesting from zoogeographic and ecological viewpoints. Thus, it is rather surprising that fishes, possibly the most extensively studied group of marine animals, have until very recently received little attention locally in either of these fields.

Early studies of Tasmanian fishes were taxonomic or provided only miscellaneous notes on species. The first extensive collection was gathered by a naturalist, T.J. Lempriere (Johnston, 1883). His specimens were subsequently described by Richardson (1839, 42a, 42b). M. Allport later constructed an unpublished catalogue of species which was used by Johnston (1883) in collating the first systematic list of Tasmanian fishes. This catalogue was updated by Johnston (1891), Lord (1922) and Lord and Scott (1924). A series of observational papers on fishes collected from this region by Scott (1934-1982) have provided many additions. These, along with a few general Australian works (e.g. McCulloch, 1929; Munro, 1956) and the results of several recent surveys (Tasmanian Fisheries Development Authority, unpublished data) form the basis of an updated guide to Tasmanian fishes (Last, Scott and Talbot, in press).

Recent studies have contributed to our knowledge of the composition of Tasmanian fish communities but published information on most remains scant. Several works relate to freshwater fishes (Frankenburg, 1974; Bennison, 1975; Andrews, 1976; Sloane, 1976; Lake and Bennison, 1977; Fulton, 1979; Lake and Fulton, 1981) but there have been fewer similar studies of marine fishes. These are limited to works on trawl fishes (Last and Harris, 1981) and reef fishes (Edgar, 1981). B. Mollison constructed an unpublished inventory of estuarine animals, including fishes, while R. Green prepared an unpublished checklist of fishes from the Tamar River. Dix (1974) provided data on fish species caught in a gill-netting efficiency study in the Derwent Estuary, but the only other multi-species works on estuarine fish relate to feeding and pollution studies (Eustace, 1974; Ratkowsky *et al.*, 1975), taxonomic studies (Johnston, 1881; Hall, 1913; Scott, 1977), miscellaneous notes (Johnston, 1883; Saville-Kent, 1897) and species lists (Scott, 1965; Waterman and Waterman, 1979).

Beach faunas are less well known and a study by Robertson (1981) on the feeding ecology of 4 seagrass species is the only previous work on these fishes. Other local studies have dealt with biological aspects of single marine species or species within a single family (Kurth, 1954; Wolfe, 1967, 70; Lovett, 1969; Walker, 1970, 72a,72b; Grant, 1971; Thein, 1972; Eustace, 1974; Last, 1975; Ratkowsky *et al.*, 1975; Webb, 1976).

The coasts of Tasmania and Victoria have been shown, in studies of intertidal invertebrates (Bennett and Pope, 1953, 60; Dartnall, 1974) to form a distinct faunal province. The name 'Maugean' (Whitley, 1932) has been widely adopted by zoogeographers to represent this Australian cool temperate province (Hedgepeth, 1957; Knox, 1960, 63; Briggs, 1974). Briggs (1974) highlighted the lack of a recent comprehensive account of Tasmanian fishes but several species were considered to be endemic. He concluded that the amount of endemism was variable, depending on the group, from about

10 - 30 % with the remaining component represented largely by elements from the adjoining warm temperate provinces.

Endemism is considered to be an important factor in characterising faunal provinces (Ekman, 1953). Shallow coastal waters, where the habitat complexity is greatest, generally contain the largest proportion of species of any marine environment. These habitats contain more species with smaller distributions than deeper offshore habitats (Pielou, 1979). Thus, inshore habitats are likely to harbour the majority of species endemic to a region, although a reliable estimate of the amount of endemism can only be made after a thorough knowledge of the distributions of species has been obtained.

There have been many ecological studies of estuarine fishes (Lenanton, 1977) but prior to 1976 when this work first commenced Australian studies were limited and these have been documented (Bayly, 1975, 80; Lenanton, 1977). Other relevant studies have been completed by Dredge (1976), Stephenson and Dredge (1976), Beumer and Harrington (1977), Robertson (1977), Bell *et al.* (1978a), Beumer (1978) Bishop and Bell (1978), Hoese (1978), Lenanton (1978), Chubb *et al.* (1979), Conacher *et al.* (1979), Bell (1980), Blaber (1980) and Gilligan (1980). Detailed faunal studies are in progress in several Australian states and an intensive study of fishes in Botany Bay, New South Wales, was recently completed (Pease *et al.*, 1980).

Victorian coasts are representative of the northern part of the cool temperate province. Studies on Western Port Bay (Shapiro, 1975; Brown, 1977) and Port Phillip Bay (Anonymous, 1973) have provided some information on coastal fish communities and a seagrass community in the former has been covered thoroughly by Robertson (1974, 77, 80) and Robertson and Howard (1978). Rigby (1979) is currently studying the fishes of the Gippsland Lakes where additional data have been collected by the Victorian Fisheries and Wildlife Division (Newell, 1978; Tunbridge, personal communication).

In comparison with those of estuaries, beach fishes have received little attention in Australia. Dybdahl (1979) provided an assessment of fish resources in Cockburn Sound, Western Australia, but the only other study on the ecology of exposed beach fishes is in progress in Western Australia (A. Robertson, personal communication).

The importance of estuaries and bays as nursery areas for recreational and commercial fish is well documented (Lenanton, 1977). Similarly, in many areas of the world, estuaries and bays are major fishing grounds (Day and Grindley, 1981). Australian warm temperate estuaries are nursery areas for several species and the adults of some are important to fisheries. An estimated 66% by weight of the New South Wales commercial fisheries production during the 1962-1972 decade (Pollard, 1976) and 32% of the Australian fisheries production in 1971-72 was estuarine dependent (Newell and Barber, 1975).

Estuarine dependence of adult and juvenile fishes in cool temperate Australian estuaries is comparatively unknown. Beinssen (1978) completed a provisional study of estuarine bay fishing in Victoria in which he listed 32 commercial species from Port Phillip Bay, Western Port Bay and the Gippsland Lakes. In 1973, landings from these estuaries totalled about 25% of Victoria's fish production.

The importance of Tasmanian estuaries and bays to commercial scale fisheries has not been discussed in detail for almost a century. Johnston (1883) listed 4 commercial species from the 'home grounds' which incorporates the shore zone and shallow estuaries. He recognised the value of these habitats as nursery areas and commented on the destructive effect of seining on juvenile fishes in these areas.

This dissertation examines aspects of the ecology and zoogeography of fishes living in sedimentary environments of the Tasmanian shore zone and coastal watershed. 'Sedimentary' refers only to habitats that have substrates consisting of unconsolidated sediments (i.e. clay, silt, mud, sands or pebbles). Substrates consisting of sedimentary rocks (i.e. sandstone, mudstone, limestone) are typical of rocky and reef habitats and were not examined in this study.

This work can be rationalised into three sections: a study of fish community structure over the entire spectrum of sedimentary habitat types of the Tasmanian shore zone ranging from estuaries to exposed beaches; a study of aspects of the ecology of fishes in 2 estuarine systems; and an assessment of the zoogeographical relationships of these fishes.

The principal aims are summarised by the following:

- to provide a simple classification and description of habitats of coastal sedimentary environments
- to ascertain the validity of these habitats as biotopes in delimiting fish communities
- to investigate diel and seasonal changes in number, size, species composition and habitat usage of fishes from a bay estuarine sandflat
- to determine community structure, trophic relationships and habitat usage of fishes from an open lagoon and an adjacent beach
- to construct a checklist of Tasmanian estuarine fishes and to examine the validity of the Remane curve when applied to these fishes
- to find evidence of a distinct Maugean fauna in fishes and to compare the familial composition of Tasmanian estuarine species with those from other temperate regions
- to assess the importance of sedimentary environments of the shore zone to recreational and commercial fisheries.

CHAPTER 2

GENERAL METHODS AND TERMINOLOGY

2:1 PRESENTATION

Some aspects of the methodology and terminology are relevant to more than one part of the study while others are specific to smaller areas. To avoid repetition, broad methods such as the selection of sampling gear, use of major terminology, and general computational procedures are presented here. More specific aspects of the methodology and descriptions of sampling areas are presented in the appropriate sections.

2:2 SAMPLING EQUIPMENT

The following gear, including a code for identification in later descriptions, was used during the study:

a) Beach seines: (S1) - 3 x 35m; uniform 13mm (knot to knot), 2 ply nylon mesh; bouyancy slightly negative; a 25m chain, link length 20mm, was sometimes attached to the ground line to prevent the net rolling.

(S2) - 3 x 15m; uniform 13mm, 2 ply nylon mesh; bouyancy slightly negative.

(S3) - 1 x 10m; uniform 13mm, 2 ply nylon mesh; neutral bouyancy.

b) Set (gill) nets: (G1) - two 50m, 57mm x 50 meshes monofilament 'mullet' nets.

(G2) - two 50m, 102mm x 25 meshes monofilament 'graball' nets.

c) Otter trawl: (O) - one 2m headline prawn trawl, 20mm mesh, 2mm cod-end

d) Plankton net (P) - one 0.25 m^2 intake funnel, 250 μ mesh size.

e) Electrofisher (E) - a Honda E800 generator producing a 220V alternating current which was rectified to either a 50 pulses sec^{-1} or 100 pulses sec^{-1} direct current.

2:3 PRESERVATION OF SPECIMENS

Specimens were intially fixed in 10% v/v formalin and those requiring examination for ecological purposes were then preserved in a 5% v/v solution. The abdominal cavities of specimens of total length greater than 10cm were incised to ensure rapid fixation of the viscera. Taxonomic material was stored in a 5% glycerophosphate-formaldehyde solution of the type outlined by Steedman (1976); small or delicate specimens were pre-anaesthetized in a 0.1% w/v tricaine or ethyl m-aminobenzoate methanesulfonate solution (MS 222).

2:4 COMPUTATIONS AND DATA STORAGE

All data were punched on to cards and stored on computer files which were then summarized on to line printer listings and microfiche . Print sheets are currently held by the author and the microfiche are stored in the Tasmanian Fisheries Development Authority Laboratory library at Crayfish Point, Taroona. Ancillary data can be obtained from the author.

All computerised analyses were performed on the CSIRONET Cyber 76 computer at Canberra.

2:5 TERMINOLOGY

The problems of usage and applicability of some ecological terms have been discussed by Hedgepeth (1957). Elaborate terminology, whilst useful, has often been subjected to conflicting definitions and authors should ensure that controversial terms are clearly defined.

The meanings of important, but potentially ambiguous, terms used in this study are explained below. Less general terms are defined in the relevant sections.

2:5:1 Estuaries, Lagoons and Marginal Zones

Coastal landforms have been defined in several ways by authorities in different disciplines. These include important coastal features such as estuaries, lagoons and the various transitional zones between marine and estuarine waters.

Estuary

The term 'estuary' has been subjected to a multiplicity of definitions (Barnes, 1974) based on hydrological themes (e.g. Ketchum, 1951; Moore, 1958; Perkins, 1974), geomorphological themes (e.g. Fowler and Fowler, 1924; Emery and Stevenson, 1957) or a combination of both themes (e.g. Odum, 1959; Cameron and Pritchard, 1963; Pritchard, 1967; Clark, 1977). The various inadequacies of each have been clearly discussed by Day (1981a) who proposed a more complete definition based on an amended version of Pritchard (1967).

His definition, which is adopted in this study is:

> "An estuary is a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage."

Clark (1977) suggested that, as a rule of thumb, an estuary should have a shoreline length in excess of three times the width of its outlet to the sea and the salt concentration should exceed $0.5^{o}/oo$. The estuarine regime thus includes brackish embayments, fiords, lagoons and tidal rivers.

Lagoon

Lagoons have been defined mainly on shape (Emery and Stevenson, 1957; Clark, 1977) and genesis (Remane and Schlieper, 1971; Roy, 1982). Day (1981a) has followed a meaning given in Webster's Dictionary, based on shape but in which no reference is made to estuaries or no salinity type is specified. In this sense 'lagoon' is not rigidly defined and includes some estuaries, freshwater lakes and arms of the sea partly enclosed by land or by coral reefs (Day, 1981a).

For the purposes of this study, a lagoon refers to a specialised type of estuary, aligned almost parallel to the coast (Shepard and Wanless, 1971), which is derived by Holocene submergence and has become partly or wholly enclosed by depositional barriers of sand and shingle (Bird, 1976). They are probably similar to closed or blind estuaries (Day, 1981a) and barrier estuaries (Roy, 1982).

Marginal Zone

In many coastal areas brackish water influences extend well outside the seaward boundaries of estuaries. McHugh (1967) regarded these offshore brackish zones as 'nektonic estuaries' and demonstrated their importance to estuarine fishes. For example, large sections of the Bering Sea and Gulfs of

Alaska and Mexico have brackish surface layers due to the close proximity of large river systems.

Australia, however, is the driest continent outside the polar regions (Warner, 1977), and in only a few areas, and then only during flooding, are these brackish zones well developed offshore. Runoff around most of the Tasmanian coast is high (Warner, 1977) and marine areas adjacent to some estuaries are penetrated by brackish water. These areas are referred to as marginal zones.

2:5:2 Components of Brackish Waters

The upper limit of the effect of the sea in an estuary is regarded as the area in which the water becomes fresh (Clark, 1977). The demarcation point between fresh and saline water has been set at many different levels ranging from 0.1^{o}/oo (Johansen, 1918) to 3^{o}/oo (Remane, 1934). Any current selection of an appropriate boundary is arbitrary (Barnes, 1974), however, as many recent authors have adopted 0.5^{o}/oo (e.g. Perkins, 1974; Clark, 1977; Day, 1981b), this figure was used herein.

Brackish waters, which form the intermediate condition between marine and freshwater conditions (McLusky, 1971), have been classified by many authors and these have been reviewed by Remane and Schlieper (1971). A slightly modified version of the "Venice System" described by Remane and Schlieper (1971) was adopted for use in this study (Table 2:1). Marine or euhaline waters have salinities of 30 - 36^{o}/oo, whereas brackish or mixohaline waters have salinities between 0.5 and 30^{o}/oo. The salinities of hyperhaline systems exceed 36^{o}/oo.

Table 2:1. Classification of brackish and marine waters based on salinity.

Zone	Salinity range $^{o}/oo$
Hyperhaline II	greater than 45
Hyperhaline I	36-45
Euhaline (marine)	30-36
Mixohaline (brackish)	0.5-30
(Mixo) - polyhaline	18-30
(Mixo) - mesohaline	5-18
(Mixo) - oligohaline	0.5-5
Limnetic (freshwater)	less than 0.5

Three other categories were added to incorporate conditions found in stratified estuaries. These included the following extremes of salinity: marine - freshwater (0 - 36^{o}/oo), lower mesohaline to marine (5 - 36^{o}/oo) and freshwater to upper mesohaline (0 - 18^{o}/oo).

2:5:3 Salinity Types of Fishes

The tolerance of organisms to variable and specific salt concentrations is important in determining their distributions in brackish regions (Remane and Schlieper, 1971) and several classifications of the salinity types of fishes have been proposed (Hedgepeth, 1957). A system proposed by Lenanton (1977) but modified slightly to correspond with the classification of brackish and marine waters, was used in this study (Table 2:2).

Table 2:2 Classification of the salinity types of fishes.

Type	Salinty range
Hyperhaline	greater than $36^{0}/oo$
Stenohaline marine	marine
Euryhaline (marine) I	marine to $18^{0}/oo$
Euryhaline (marine) II	marine to $5^{0}/oo$
Euryhaline III	marine to freshwater
Euryhaline (freshwater) IV	$30^{0}/oo$ to freshwater
Euryhaline (freshwater) V	$18^{0}/oo$ to freshwater
Stenohaline freshwater	$5^{0}/oo$ to freshwater

Hyperhaline species also capable of inhabiting brackish and freshwater were further categorized as hypereuryhaline I - III, depending on the level of penetration.

2:5:4 Residential Characteristics of Estuarine Fishes

The residential status of fishes in estuaries is dependent not only on their tolerance to salinity changes but also on their breeding and migratory habits. Various status assessment schemes have been proposed by Day (1951), McHugh (1967), Tyler (1971), Barnes (1974), Perkins (1974), Hoese (1978), Lenanton (1978) and others but are probably best summarised by Day, Blaber and Wallace (1981). Five classes are recognised and these are summarised as follows:

a) marine migrants - these are marine species which venture into estuaries seasonally (temporary residents), incidentally (transients) or as juveniles (ontogenetic residents).

b) anadromous fishes - these are fishes that migrate from the sea to freshwater to breed.

c) catadromous fishes - this group includes species that migrate from freshwater to the sea to breed.

d) estuarine fishes - these are resident species that grow, breed and feed in estuaries.

e) anomalous fishes - this small group includes fishes whose breeding and migratory habits do not fit any well-defined category. In the Australian region, it applies particularly to freshwater migrants, including euryhaline and diadromous species, and freshwater species capable of breeding in estuaries.

2:5:5 Spatial Characteristics of Fishes

Marine ecosystems have been divided in many ways (Lagler *et al.*, 1962) and the breakdown of spatial components is often inconsistent (Christy and Scott, 1965). The terms adopted in this study are defined below:

a) benthic fishes - in strict terms, refers to species living on the bottom (Abercrombie *et al.*, 1951; Hela and Laevastu, 1961; Leftwich, 1967).

b) benthopelagic fishes - refers mostly to active swimming species living in association, but not generally in contact, with the substrate and representing part of a wide category of nekton (Marshall, 1967).

c) demersal fishes - includes both 'benthic' and 'benthopelagic' species; although mostly used in a fisheries sense to refer to offshore faunas living in association with the bottom, the term has been applied to shallow water faunas (Warburton, 1978).

d) pelagic fishes - refers collectively to the other planktonic and nektonic components of Hedgepeth's (1957) neritic and oceanic zones.

CHAPTER 3

TAXONOMY

The accurate identification of component species is an important prerequisite for meaningful ecological or zoogeographic studies. A considerable amount of alpha taxonomy was initially required to delimit the fauna because there was no definitive publication on the Tasmanian fish fauna available at the commencement of this study. Species sampled are listed in Table 3:1

Several undescribed species and new Tasmanian records were collected and these have been lodged in the Queen Victoria Museum and Art Gallery (QVM) and the Tasmanian Museum and Art Gallery (TM).

3:1 UNDESCRIBED SPECIES

At least 11 new species were obtained during this study (Table 3:2) and two, *Taratretis derwentensis* and *Dasyatis guileri*, have been described by the author (Last, 1978, 79). The other species were examined by authorities, who confirmed their status, and will be described in due course. Epithets of undescribed species were designated in the usual way (i.e. sp.) but the use of non-sequential identification numbers for gobiids followed an unpublished key by D.F. Hoese.

A goby, *Favonigobius* sp., collected from freshwater on King Island, is unlike other southern Australian species and may also be new.

Table 3:1. List of species collected during the sampling programme.

GEOTRIIDAE		
Geotria australis	Gray, 1851	Pouched Lamprey
MORDACIIDAE		
Mordacia mordax	(Richardson, 1846)	Short-headed Lamprey
SCYLIORHINIDAE		
Cephaloscyllium laticeps	(Dumeril, 1853)	Draughtboard Shark
CARCHARHINIDAE		
Galeorhinus australis	(Macleay, 1881)	School Shark
Mustelus antarcticus	Günther, 1870	Gummy Shark
SQUALIDAE		
Squalus megalops	(Macleay, 1881)	Spiked Dogfish
Squalus acanthias	Linnaeus, 1758	White-spotted Dogfish
PRISTIOPHORIDAE		
Pristiophorus nudipinnis	Günther, 1870	Southern Saw Shark
TORPEDINIDAE		
Narcine tasmaniensis	Richardson, 1840	Tasmanian Numbfish
RAJIDAE		
Raja lemprieri	Richardson, 1845	Thornback Skate
Raja whitleyi	Iredale, 1938	Melbourne Skate
UROLOPHIDAE		
Urolophus cruciatus	(Lacepede, 1804)	Banded Stingaree
Urolophus paucimaculatus	Dixon, 1969	Sparsely-spotted Stingaree
MYLIOBATIDAE		
Myliobatis australis	Macleay, 1881	Eagle Ray
CALLORHYNCHIDAE		
Callorhynchus milii	Bory de St Vincent, 1823	Elephant Fish
CLUPEIDAE		
Clupea bassensis	(McCulloch, 1911)	Sprat
DUSSUMIERIIDAE		
Spratelloides robustus	Ogilby, 1897	Blue Sprat
ENGRAULIDAE		
Engraulis australis	(White, 1790)	Australian Anchovy
ANGUILLIDAE		
Anguilla australis	Richardson, 1841	Short-finned Eel
Anguilla reinhardtii	Steindachner, 1867	Long-finned Eel
CONGRIDAE		
Conger verreauxi	Kaup, 1856	Verreaux's Conger Eel
OPHICHTHIDAE		
Muraenichthys breviceps	Günther, 1876	Short-headed Worm Eel
SALMONIDAE		
Salmo trutta	Linnaeus, 1758	Brown Trout
RETROPINNIDAE		
Retropinna tasmanica	McCulloch, 1920	Tasmanian Smelt
PROTOTROCTIDAE		
Prototroctes maraena	Günther, 1864	Australian Grayling
APLOCHITONIDAE		
Lovettia sealii	(Johnston, 1883)	Tasmanian Whitebait

Table 3:1 (cont.)

GALAXIIDAE		
Galaxias brevipinnis	Günther, 1866	Climbing Galaxias
Galaxias maculatus	(Jenyns, 1842)	Common Jollytail
Galaxias truttaceus	Cuvier, 1816	Spotted Mountain Trout
GONORYNCHIDAE		
Gonorynchus greyi	(Richardson, 1845)	Beaked Salmon
MORIDAE		
Pseudophycis bachus	(Bloch & Schneider, 1801)	Red Cod
MERLUCCIIDAE		
Macruronus novaezelandiae	(Hector, 1871)	Blue Grenadier
OPHIDIIDAE		
Genypterus blacodes	(Schneider, 1801)	Pink Ling
Genypterus sp.		Rock Ling
BRACHIONICHTHYIDAE		
Brachionichthys hirsutus	(Lacepede, 1804)	Spotted Handfish
HEMIRAMPHIDAE		
Hyporhamphus melanochir	(Valenciennes, 1846)	South Australian Garfish
ATHERINIDAE		
Atherinosoma microstoma	(Günther, 1861)	Small-mouthed Hardyhead
Atherinosoma presbyteroides	(Richardson, 1843)	Silverfish
Atherinason esox	(Klunzinger, 1872)	Pike-headed Hardyhead
Atherinason hepsetoides	(Richardson, 1843)	Richardson's Hardyhead
Atherinason sp.		Short-headed Hardyhead
ZEIDAE		
Cyttus australis	(Richardson, 1843)	Silver Dory
SYNGNATHIDAE		
Hippocampus abdominalis	Lesson, 1827	Big-bellied Sea Horse
Hippocampus breviceps	Peters, 1870	Short-headed Sea Horse
Hyselognathus rostratus	Waite & Hale, 1921	Knife-snouted Pipefish
Leptoichthys fistularius	Kaup, 1853	Brushtailed Pipefish
Leptonotus costatus	Waite & Hale, 1921	Deep-bodied Pipefish
Leptonotus semistriatus	Kaup, 1853	Half-banded Pipefish
Lissocampus runa	(Whitley, 1931)	Javelin Pipefish
Stigmatopora argus	(Richardson, 1840)	Spotted Pipefish
Stigmatopora nigra	Kaup, 1853	Wide-bodied Pipefish
Stipecampus cristatus	(McCulloch & Waite, 1918)	Ring-backed Pipefish
Syngnathus curtirostris	Castlenau, 1872	Pug-nosed Pipefish
Syngnathus phillipi	Lucas, 1891	Port Phillip Pipefish
Syngnathus poecilolaemus	Peters, 1869	Long-snouted Pipefish
Syngnathus tuckeri	Scott, 1942	Tucker's Pipefish
Urocampus carinirostris	Castelau, 1872	Hairy Pipefish
SCORPAENIDAE		
Gymnapistes marmoratus	(Cuvier, 1829)	Soldier Fish
Neosebastes scorpaenoides	Guichenot, 1867	Common Gurnard Perch
Scorpaena ergastulorum	Richardson, 1842	Common Red Rock Cod
TRIGLIDAE		
Chelidonichthys kumu	(Lesson & Garnot, 1826)	Red Gurnard
Paratrigla papilio	(Cuvier, 1829)	Spiny Gurnard
Paratrigla vanessa	(Richardson, 1839)	Butterfly Gurnard
Pterygotrigla polyommata	(Richardson, 1839)	Latchet
PLATYCEPHALIDAE		
Platycephalus bassensis	Cuvier, 1829	Sand Flathead
Platycephalus castelnaui	Macleay, 1881	Castelnau's Flathead
Platycephalus laevigatus	Cuvier, 1829	Rock Flathead
PEGASIDAE		
Acanthopegasus lancifer	(Kaup, 1861)	Sea Moth
PLESIOPIDAE		
Trachinops caudimaculatus	McCoy, 1890	Blotch-tailed Trachinops

Table 3:1 (cont.)

KUHLIIDAE		
Nannoperca australis	Günther, 1861	Southern Pigmy Perch
DINOLESTIDAE		
Dinolestes lewini	(Griffith, 1834)	Long-finned Pike
APOGONIDAE		
Siphamia cephalotes	Castelnau, 1875	Wood's Siphon Fish
Apogon conspersus	Klunzinger, 1872	Cardinalfish
SILLAGINIDAE		
Sillago bassensis	Cuvier, 1829	School Whiting
POMATOMIDAE		
Pomatomus saltator	Linnaeus, 1766	Tailor
CARANGIDAE		
Caranx georgianus	Valenciennes, 1833	Silver Trevally
Trachurus declivis	(Jenyns, 1841)	Jack Mackerel
ARRIPIDAE		
Arripis trutta esper	Whitley, 1951	Western Australian Salmon
Arripis trutta marginata	(Cuvier, 1828)	Eastern Australian Salmon
SPARIDAE		
Acanthopagrus butcheri	(Munro, 1949)	Black Bream
MULLIDAE		
Upeneichthys lineatus	(Bloch & Schneider, 1801)	Blue-spotted Goatfish
Upeneus tragula	Richardson, 1846	Bar-tailed Goatfish
SCORPIDAE		
Atypichthys strigatus	(Günther, 1860)	Mado Sweep
KYPHOSIDAE		
Girella elevata	Macleay, 1881	Black Drummer
Girella tricuspidata	(Quoy & Gaimard, 1824)	Luderick
ENOPLOSIDAE		
Enoplosus armatus	(White, 1790)	Old Wife
CHEILODACTYLIDAE		
Nemadactylus macropterus	(Bloch & Schneider, 1801)	Morwong
LATRIDAE		
Latridopsis forsteri	(Castelnau, 1872)	Bastard Trumpeter
MUGILIDAE		
Aldrichetta forsteri	(Valenciennes, 1836)	Yellow-eyed Mullet
Mugil cephalus	Linnaeus, 1758	Sea Mullet
Myxus elongatus	Günther, 1861	Sand Mullet
LABRIDAE		
Pseudolabrus tetricus	(Richardson, 1840)	Blue-throated Wrasse
Dotalabrus aurantiacus	(Castelnau, 1872)	Castelnau's Wrasse
ODACIDAE		
Neoodax balteatus	(Valenciennes, 1839)	Little Rock Whiting
Neoodax radiatus	(Quoy & Gaimard. 1835)	Long-rayed Rock Whiting
Neoodax semifasciatus	(Valenciennes, 1840)	Blue Rock Whiting
Siphonognathus argyrophanes	Richardson, 1858	Tubemouth
URANOSCOPIDAE		
Kathetostoma laeve	(Bloch & Schneider, 1801)	Common Stargazer
LEPTOSCOPIDAE		
Crapatalus arenarius	McMulloch, 1915	Common Sandfish
Crapatalus sp.		Pink Sandfish
BOVICHTHYIDAE		
Bovichthys variegatus	(Richardson, 1846)	Dragonet
Pseudaphritis urvillii	(Cuvier & Valenciennes, 1831)	Congolli

Table 3:1 (cont.)

TRIPTERYGIIDAE		
Forsterygion gymnotum	Scott, 1977	Bare-backed Threefin
Forsterygion multiradiatum	Scott, 1977	Many-rayed Threefin
CLINIDAE		
Cristiceps argyropleura	Kner, 1865	Silver-sided Weedfish
Cristiceps australis	Valenciennes, 1836	Crested Weedfish
Heteroclinus adelaidae	Castelnau, 1872	Adelaide Weedfish
Heteroclinus forsteri	(Castelnau, 1872)	Forster's Weedfish
Heteroclinus heptaeolus	(Ogilby, 1885)	Ogilby's Weedfish
Heteroclinus johnstoni	(Saville-Kent, 1886)	Johnston's Weedfish
Heteroclinus macrophthalmus	Hoese, 1976	Large-eyed Weedfish
Heteroclinus perspicillatus	(Valenciennes, 1836)	Common Weedfish
Heteroclinus wilsoni	(Lucas, 1890)	Wilson's Weedfish
Ophiclinus gracilis	Waite, 1906	Black-backed Snake Blenny
BLENNIDAE		
Pictiblennius tasmanianus	(Richardson, 1849)	Tasmanian Blenny
ELEOTRIDAE		
Philypnodon grandiceps	(Krefft, 1864)	Big-headed Gudgeon
GOBIIDAE		
Amoya bifrenatus	(Kner, 1865)	Bridled Goby
Amoya frenatus	(Günther, 1861)	Falsely-bridled Goby
Callogobius mucosus	(Günther, 1872)	Sculptured Goby
Favonigobius tamarensis	(Johnston, 1883)	Tamar Goby
Favonigobius lateralis	(Macleay, 1881)	Long-finned Goby
Favonigobius sp.		King Island Goby
Nesogobius hinsbyi	(Johnston, 1903)	Orange-spotted Goby
Nesogobius pulchellus	(Castelnau, 1872)	Castelnau's Goby
Nesogobius sp. 2		Girdled Goby
Nesogobius sp. 3		Rotund Goby
Nesogobius sp. 5		Twin-barred Goby
Nesogobius sp. 7		Opalescent Goby
Pseudogobius olorum	(Sauvage, 1880)	Blue-spot Goby
Tasmanogobius lordi	Scott, 1935	Lord's Goby
Tasmanogobius sp. 1		Marine Goby
Tasmanogobius sp. 3		Lagoon Goby
GEMPYLIDAE		
Thyrsites atun	(Euphrasen, 1791)	Snoek
CENTROLOPHIDAE		
Seriolella brama	(Günther, 1860)	Warehou
Seriolella punctata	(Bloch & Schneider, 1801)	Spotted Trevalla
GOBIESOCIDAE		
Alabes dorsalis	(Richardson, 1848)	Red-banded Shore Eel
Alabes parvulus	(McCulloch, 1909)	Pigmy Shore Eel
CALLIONYMIDAE		
Callionymus calauropomus	Richardson, 1844	Common Stinkfish
Callionymus papilio	Günther, 1864	Painted Stinkfish
BOTHIDAE		
Arnoglossus bassensis	Norman, 1926	Bass Strait Flounder
PLEURONECTIDAE		
Ammotretis liturata	(Richardson, 1843)	Spotted Flounder
Ammotretis rostratus	Günther, 1862	Long-snouted Flounder
Rhombosolea tapirina	Günther, 1862	Greenback Flounder
Taratretis derwentensis	Last, 1978	Derwent Flounder
MONACANTHIDAE		
Acanthaluteres spilomelanurus	(Quoy & Gaimard, 1824)	Bridled Leatherjacket
Brachaluteres jacksonianus	(Quoy & Gaimard, 1824)	Pigmy Leatherjacket
Eubalichthys gunnii	(Günther, 1870)	Velvet Leatherjacket
Meuschenia freycineti	(Quoy & Gaimard, 1824)	Six-spined Leatherjacket
Penicipelta vittiger	(Castelnau, 1873)	Toothbrush Leatherjacket
OSTRACIONTIDAE		
Aracana aurita	(Shaw, 1798)	Shaw's Cowfish
TETRAODONTIDAE		
Contusus richei	(Freminville, 1813)	Barred Toadfish
Contusus sp.		Prickly Toadfish
Torquigener glaber	(Freminville, 1813)	Smooth Toadfish
DIODONTIDAE		
Dicotylichthys myersi	Ogilby, 1910	Myer's Porcupinefish
Diodon nicthemerus	Cuvier, 1818	Globefish

Table 3:2 Undescribed species collected during this study.

Family/Species	Museum Registration Number	Author/Authority
DASYATIDAE		
Dasyatis guileri	QVM 1978/5/108	Last (1979)
ATHERINIDAE		
Atherinason sp.	TM D1608	Ivantsoff (1)*
LEPTOSCOPIDAE		
Crapatalus sp.	TM D1710	Last and Munro (2)*
GOBIIDAE		
Nesogobius sp. 2	TM D1609	Hoese (3)*
Nesogobius sp. 3	TM D1711	" "
Nesogobius sp. 5	TM D1712	" "
Nesogobius sp. 7	TM D1713	" "
Tasmanogobius sp. 1	TM D1714	" "
Tasmanogobius sp. 3	TM D1715	" "
PLEURONECTIDAE		
Taratretis derwentensis	TM D1305	Last (1978)
TETRAODONTIDAE		
Contusus brevicaudus	TM D1716	Hardy (1981)

*Addresses of authorities

(1) Dr. W. Ivantsoff, Macquarie University, Sydney, New South Wales.

(2) Mr. I.S.R. Munro, C.S.I.R.O., Cronulla, New South Wales.

(3) Dr. D.F. Hoese, Australian Museum, Sydney, New South Wales.

3:2 NEW TASMANIAN RECORDS

Five specimens represent new locality records of species for Tasmanian waters (Table 3:3).

Table 3:3 New Tasmanian records collected during this study

Species	Museum Registration Number
Hypselognathus rostratus (Waite and Hale, 1921)	TM D1717
Leptonotus costatus Waite and Hale, 1921	TM D1718
Platycephalus castelnaui Macleay, 1881	TM D1719
Upeneus tragula Richardson, 1846	TM D1720
Heteroclinus wilsoni (Lucas, 1890)	TM D1721
Amoya frenatus (Günther, 1861)	TM D1722
Dicotylichthys myersi (Ogilby, 1910)	TM D1723

Two others have been collected previously from this area but their occurrence is presently undocumented. *Heteroclinus wilsoni* is listed from Tasmania in an unpublished key to the clinids (D.F. Hoese, personal communication) and *Platycephalus castelnaui,* which is common in areas of Bass Strait, appears to have been misidentified as *P. fuscus* Cuvier, an eastern Australian species.

3:3 MISCELLANEOUS NOTES ON SPECIES

Scientific nomenclature used in this study is based on recent taxonomic studies. Because some names are not widely used, they require explanation.

SCYLIORHINIDAE

Cephaloscyllium laticeps (Dumeril, 1853)

This species is more widely known in southeastern Australia as *C. isabella laticeps* Whitley. Springer (1979) recognized *C. laticeps* as a valid species.

CARCHARHINIDAE

Carcharhinus brachyurus (Günther, 1870)

This species is a senior synonym of *C. greyi greyi* Owen (Garrick, 1982).

SQUALIDAE

Squalus acanthias Linnaeus, 1758

This species is a senior synonym of *S. kirki* Phillips (Garrick, 1960).

CONGRIDAE

Conger verreauxi (Kaup, 1856)

Although Kanazawa (1958) lists two species from southern Australia, only *C. wilsoni* (Bloch and Schneider) is recognized in species lists. An examination of Tasmanian material indicates that *C. verreauxi* is the common species; *C. wilsoni* was not present in local collections. Doak (1972) suggested that the latter is a warm water species in New Zealand.

EXOCOETIDAE

Hirundichthys rondeletii (Valenciennes, 1846)

Previously placed in *Danichthys* (Bruun, 1935), the species was transferred to *Hirundichthys* by Parin (1961).

MORIDAE

Pseudophycis bachus (Bloch and Schneider, 1801)

This species appears to have been confused with *P. barbatus* Günther. Both species are referred to as *Physiculus* in Australian literature (Walker, 1970, 79; Anonymous, 1973; Lenanton, 1974 and others) but they lack luminous organs which are diagnostic of this genus (Cohen, personal communication).

P. barbatus is claimed to be a common commercial species in Tasmanian waters (Walker, 1972a) but it is much less abundant than *P. bachus*. A description and illustration, provided by Walker (1970) of *P. barbatus*, is undoubtedly of *P. bachus*. Historical records of these species must be treated with some reservation.

OPHIDIIDAE

Genypterus sp.

Two species of *Genypterus* were collected during the course of this study. The common coastal species, *G.* sp., which appears to be conspecific with *G. tigerinus* Klunzinger, is described in Australian references as *G. blacodes* (Schneider) (Scott *et al.*, 1974); the latter is a senior synonym of the second Tasmanian species, *G. microstomus* Regan.

ATHERINIDAE

Atherinosoma presbyteroides (Richardson, 1843)

This species is a senior synonym of *Taeniomembras tamarensis* (Johnston) (Ivantsoff, 1978).

Atherinason esox (Klunzinger, 1872)

Previously placed in *Stenatherina*, the species was transferred to *Atherinason* by Ivantsoff (1978)

Atherinason hepsetoides (Richardson, 1843)

This species, described from material from Port Arthur, is the senior synonym of *A. dannevigi* (McCulloch) (Ivantsoff, 1978).

SYNGNATHIDAE

Stipecampus cristatus (McCulloch and Waite, 1918)

Previously placed in *Ichthyocampus*, the species was transferred to *Stipecampus* by Dawson (1977).

Solegnathus spinosissimus (Günther, 1870)

Three species of *Solegnathus* have been recorded from Tasmanian waters: *S. fasciatus* (Günther), *S. robustus* McCulloch, and *S. spinosissimus*. Although the genus needs revising (Dawson, 1980), *S. spinosissimus* appears to be the most common species found in shallow inshore waters of Tasmania (Dawson, personal communication).

SCORPAENIDAE

Neosebastes scorpaenoides Guichenot, 1867

The species was recorded by Lord and Scott (1924) from Tasmania but subsequently appears to have been mistaken for other *Neosebastes* species (Eschmeyer, personal communication).

PLESIOPIDAE

Trachinops caudimaculatus McCoy, 1890

Allen (1977), in a revision of the genus *Trachinops*, did not mention a species described from Tasmania, *T. rodwayi* (Johnston) and recognized only *T. caudimaculatus* from these waters. Scott (1978) distinguished *T. rodwayi* from the latter on fin shape, dentition and predorsal scale form. As these characters were found to be variable in Tasmanian populations, only *T. caudimaculatus* is recognized here.

APOGONIDAE

Apogon conspersus (Klunzinger, 1872)

The coastal temperate apogonids are currently being revised and the common shallow water species occurring in this region is *Apogon conspersus* (J.R. Paxton, personal communication). This species is conspecific with the form identified locally by Scott (1978) as *Vincentia novaehollandiae* (Cuvier).

ARRIPIDAE

Arripis trutta (Bloch and Schneider, 1801)

Subspecies, *A. trutta marginata* (Cuvier) and *A. trutta esper* (Whitley) are now regarded as valid species (MacDonald, 1980). Due to difficulties in distinguishing these forms in the field, all *Arripis* were recorded collectively as *A. trutta*; specific differences were not appreciated at the time of sampling. However, *A. trutta marginata* is distinctly more abundant in this region.

Juvenile *A. trutta* have been misidentified by Scott (1976) as an allied species *A. georgianus* (Valenciennes) which does not occur in Tasmanian waters.

ODACIDAE

The family has been revised by M. Gomon and J.R. Paxton and several generic name changes will be implemented (Gomon, personal communication).

BOVICHTHYIDAE

Bovichthys variegatus (Richardson, 1846)

Two species of *Bovichthys* are recognized from the Tasmanian region

(Regan, 1914): *B. variegatus* and *B. angustifrons* Regan. No additional specimens of *B. angustifrons* have been collected since the species was first described indicating that it is either very rare or, more likely, conspecific with *B. variegatus*.

CHAPTER 4

HABITATS AND FISH FAUNAL ASSEMBLAGES OF THE TASMANIAN SHORE ZONE AND COASTAL WATERSHED.

4:1 INTRODUCTION

The concept of community structure is important in appreciating the manner in which biological systems work in the sea (Perkins, 1974). Early classifications were carried out on benthic invertebrate communities (Petersen, 1913), but many recent studies have been extended to fish assemblages and patterns of community structure; these have been discussed in detail by Helfman (1978). Most Australian works on fishes have dealt with biological aspects of certain community members and few have concentrated on the structure of the entire community or the relationships between associated communities.

Marine ecosystems revolved around the interactions between organisms and their environments (Watts, 1971). Unlike the meiofauna of benthic communities, which can migrate into the sediments (Dye and Furstenburg, 1981), most fishes must move within the aquatic environment to avoid unfavourable physical conditions. Consequently, the delineation of physical parameters is an important prerequisite for interpreting the structure of fish communities and thus providing a basis for community classifications.

Systems of classification of biotic communities are important in the management and preservation of ecosystems (Dasmann, 1972). Attempts by major organisations to construct classifications, such as those recommended by the International Union for Conservation of Nature and Natural Resources

Scheme (Anonymous, 1974), have been criticised for excluding marine environments (Ray, 1975). Problems inherent in classifying these environments have been highlighted by Ray (1975) who presented a tripartite scheme which was based on habitats and on adaptations of earlier proposals structured on zoogeographic (Ekman, 1953) and coastal regions (Ketchum, 1972).

Coasts have been classified according to a wide range of criteria and several of these have been reviewed by King (1972). Most were based on geomorphological characteristics and cannot be applied exclusively to ecological situations. Factors such as substrate, exposure, temperature and salinity are generally more important in influencing the distributions of biota than the genetic features of coastal landforms.

Davies (1964) provided a dynamic classification of coastlines based mainly on wave climates but, as his approach was applied to major geographic regions, it is not useful on a local scale. Nevertheless, the importance of exposure in characterising biological communities has been highlighted by many authors (e.g. Moore, 1958; Smith and Carlton, 1975) and has formed the basis of most biologically founded classifications of coastal marine habitats (e.g. Guiler, 1952; Bennett and Pope, 1960; Clark, 1977; and Eleftheriou, 1979). Estuaries have been subjected to a similar surfeit of classifications (Day, 1981a).

The importance and the general poor acceptance of biological factors in the classification of coasts by geographers has been stressed by Davies (1972). He proposed that a question of scale should be used in categorizing coasts with biological factors best characterising the lowest order scale, the shore. The validity of these classifications could be tested by examining the infra-structural components which, in this case, would consist of the various areas within a geographical region. This approach would provide a reference base for regional comparisons.

A recent report by the Tasmanian Conservation Trust (Goldin, 1980) has made an important contributuion to our knowledge of the Tasmanian coastal environment. Coastal usage and sites of interest have been classified in various ways but, although the coast was divided into 92 separate land units and the geology, geomorphology and vegetation described, no attempt was made to classify the aquatic environments. Guiler (1952) has classified rock platforms based on exposure but a classification of aquatic habitats over soft-bottom substrates has not been attempted for the shore zone of Tasmania.

An ideal classification, useful for management purposes, would be one in which community types are predictable and habitats are representative of biotopes. This situation, however, is rarely found because most marine communities are associations and are often difficult to delineate by biotopic criteria (Stephenson, 1973). Nevertheless, the validity of the concepts of biotopes and biocoenoses, when applied to fish communities, has been surprisingly understudied. Horn and Allen (1976) have examined faunal resemblance of marine fishes in Californian bays and estuaries but, to the author's knowledge, there have been no published regional studies on shore fish communities over a wide range of sedimentary habitat types.

The following study attempts to provide (1) a simple description and classification of coastal types, useful for management purposes and (2) to examine the community characteristics of fishes living in these environments.

4:2 METHODS

4:2:1 Sampling Sites

Four hundred and ninety seven sites were sampled from the shore zones of the 16 coastal regions discussed in Section 4:3:4 and their distributions are illustrated in Figure 4:1. The habitat types of these localities and their geographic co-ordinates are given in Appendix 4:2.

The sampling programme consisted of a series of preliminary trials during 1977 followed by seasonal excursions around Tasmania in 1978. King and Flinders Island sites were sampled half-yearly in winter and summer while the Kent Group was visited only in March 1979. Many sites were also sampled out of season and the programme ended in February, 1980. During this period, 793 diurnal samples were taken using seines S1 - 3. Additional data were obtained by using set nets (G1 - 2), the electrofisher (E) and the otter trawl (T) but these, other than to provide distributional information on species, are not presented herein.

Most sites were accessible by vehicle but many less accessible areas were reached in a small power-driven boat. Access to the remote waterways of Port Davey was provided by the Tasmanian Fisheries Development Authority patrol vessel, F.V. "D'Entrecasteaux". Nevertheless,some extremely isolated and exposed areas of western and southern Tasmania proved difficult to reach and these were not sampled.

4:2:2 Sampling Procedures

At each sample the following information was recorded on field data sheets then transcribed on to coded sheets (Appendix 4:1) and punched on to computer cards.

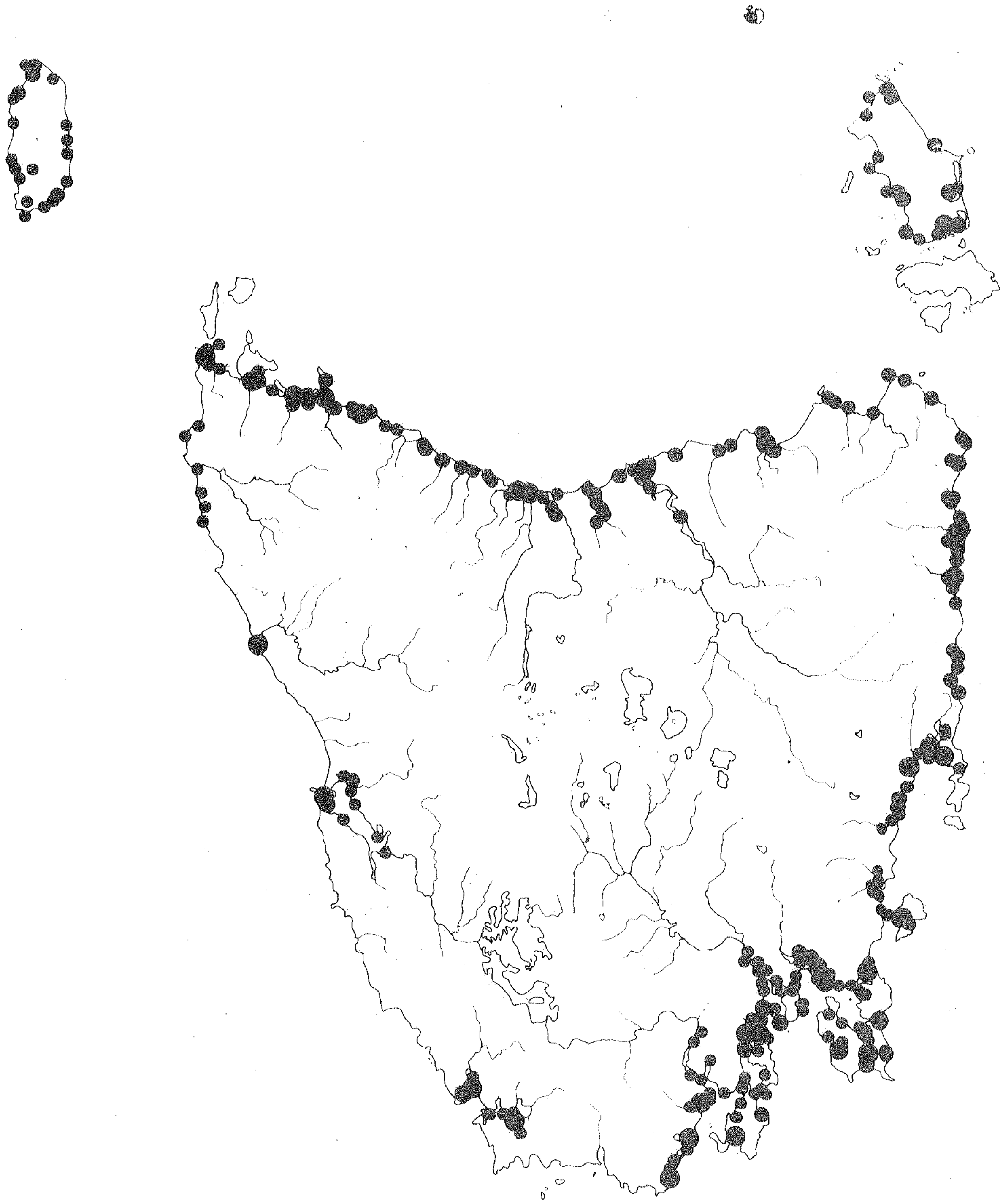


Fig. 4:1. Distribution of sampling sites around Tasmania. Small dots represent a single site; medium dots, 2 overlapping sites; large dots, more than 2 overlapping sites.

Site Data

Area and site numbers, date and time of day were used to identify samples. Coded information on substrate characteristics, gear type, area swept and the quantitative status of samples was also recorded.

The large seine net (S1) was hauled over an area of approximately 200, 250, 750 or 1,000 m^2 depending on the form and depth profile of the site. The effective area swept, calculated on distance towed, was generally predetermined. Appropriate adjustments were made to accomodate variations in the gape of the net or the effects of currents on the tow. If environmental conditions seriously hindered proper functioning of the net, hauls were regarded as non-quantitative. Samples taken with the smaller seines (S2, 3) were arranged to sweep an estimated area of 100 m^2 . However, only data obtained from samples using (S1) were used in quantitative analyses.

Substrates were broadly identified as mud, sand or pebbles using the Wentworth Scale (Holme and McIntyre, 1971).

Site Classification

Sites were allocated a provisional habitat designation based on evidence from existing unpublished information. These were later re-categorised according to the classification of Tasmanian sedimentary habitats (Section 4:3:3) which included new information obtained during the sampling programme.

The habitat types, 55 in total and henceforth referred to as 'minor habitats', were derived from a combination of environmental factors such as exposure, substrate characteristics, topographic position, geomorphology, bathymetry and hydrology. The characteristics of minor habitats are presented and discussed in future sections.

Hydrological Data

Parameters measured included temperature, salinity, tidal situation and water surface conditions.

Temperatures were recorded 30 cm below the surface using a thermometer graduated in 0.1^{0}C increments. At shallower sampling sites temperatures were taken midway between the surface and the bottom.

A Yellow Springs YSI33 salinometer was used to provide vertical profiles of salinity and temperature. The salinity characteristics of the sites were ordered into one of the following categories in situations where a halocline or salinity gradient was absent: (1) less than 1^{0}/oo, (2) 1 - 5^{0}/oo, (3) 5 - 18^{0}/oo, (4) 18 - 30^{0}/oo, (5) 30 - 36^{0}/oo, (6) 36 -45^{0}/oo and (7) greater than 45^{0}/oo. Where a well defined halocline was present the following ranges were used : (8) 0 - 18^{0}/oo, (9) 0 - 36^{0}/oo and (10) 5 - 36^{0}/oo. As the salinometer was graduated in integral units, 1^{0}/oo (not 0.5^{0}/oo) was used as the boundary between fresh and brackish waters.

The tidal position during each sampling period was categorised as high, half out, low or half in based on calculations and data supplied from tide charts (Marine Board Tide Tables, 1977-1980). Hauls completed over areas normally exposed at low tide were recorded separately as intertidal.

Water surface conditions were classified according to the state of sea code as outlined by Coleman (1981).

Biological Data

Fish species were allotted a 3 digit identifier code and their presence in a sample was denoted by an abundance value on the coded punch sheet (see Appendix 4:1). Abundances were graded into the following classes: (1) 1-2, (2) 3-9, (3) 10-99, (4) 100-999 and (5) greater than 1,000 individuals. The 'principal species',or most abundant species taken in a sample, was identified by the addition of 5 to its abundance code. In situations where the initial code was 5 (i.e. greater than 1,000 individuals), this value became 0.

Information on vegetative characteristics was also recorded at each site. The term 'seagrass' has been used to refer to flowering plants restricted to life in marine conditions (Aston, 1973), but its use here includes those species found in brackish habitats. These were designated by the following categories: (1) absent, (2) *Zostera* only, (3) *Heterozostera* only, (4) *Posidonia* only, (5) *Amphibolis* only, (6) *Ruppia* dominant, (7) *Zostera* and *Heterozostera*, (8) *Heterozostera* and *Posidonia* and (9) freshwater plants. Algae were recorded as present or absent.

4:2:3 Analytical Procedures

Few analytical techniques have been uniformly accepted by modern day ecologists. Methods of handling multivariate statistical data are constantly being improved as computers increase in sophistication (Pielou, 1977). The 'best' method of analysing a data set is difficult to assess and in many cases the selection of a technique may be more subjective than the results extracted from the analysis (Pielou, 1977).

Binary Discriminant Analysis

Strahler (1978) discussed reasons why gradient analysis, principal components analysis and multiple regression analysis are sometimes inappropriate techniques for investigating species-environment relationships. He proposed, instead, a binary discriminant analysis (B.D.A.) and presented a detailed account of its function, application and problems.

In summary, the B.D.A. identifies the binary variables (i.e. species) and their associated trends that are most important in discriminating between groups (i.e. habitat types or environmental parameters).

The analysis is a two-step procedure. Firstly, a set of contingency tables based on the presence/absence of species is constructed. The interactions between species and group factors are determined from the G-statistic (see Sokal and Rohlf, 1969); only those species above a particular significance level are included in the second step.

Species cells exhibiting significant group relationships are then converted from frequency counts to standardized residuals (see Haberman, 1973) and can now be analysed by a principal components analysis package programme BMDP4M (Dixon, 1970).

These analyses structurally resemble 2 factor analyses. The first, the Q-mode analysis, takes environmental groups as variables and species as cases, and constructs orthogonal canonical factors which represent uncorrelated trends that best separate the groups. Scores obtained for each species can be plotted in multidimensional hyperspace. The second analysis, the R-mode B.D.A., uses a transposed input matrix, and groups with similar environmental responses may be identified. This latter objective necessitates varimax rotation to maximize the definition of such groups.

Cluster Analysis

There has been considerable discussion on the many ways of measuring intergroup similarity (e.g. Cormack, 1971; Goodall, 1973; Stephenson, 1973). The two agglomerative techniques, centroid and furthest neighbour cluster analyses, used here were taken from a GENSTAT package of statistical programmes (Alvey *et al.*, 1977). In summary, these techniques commence with all groups in separate clusters. Group data can be in most forms (i.e. continuous, meristic, binary, multistate or ranked). Clusters with the highest similarities are merged and similarities between the new cluster and all the other clusters are redefined. The process is repeated until all groups belong to a single cluster which can be represented by a dendrogram. In centroid analysis the re-calculated similarity is the weighted mean of similarities between each of the 2 merged clusters and any third cluster. For furthest neighbour analysis, the similarity between 2 clusters is the least similarity between any 2 units, one in each cluster.

For analyses used in this chapter, data consisted of occurrence information for species at each habitat type. The presence of species in a habitat type was represented by 1, whereas an absence was represented by 0; matching zeros were deleted. Similarity matrices for all analyses are provided in Appendix 4:6.

4:2:4 Presentation

The method of presentation for the sections on community structure requires brief explanation. To avoid needless repetition, results and discussion are presented together; general points and conclusions are covered in comments sections.

Firstly, the numbers of species caught in habitat types are summarised. Standard indices for representing diversity (e.g. Shannon-Weaver function, equitability index and evenness index), although calculated, were not considered to be useful and are not presented (see also Chapter 5). A B.D.A. analysis of the species/habitat relationships precedes more general summaries of the patterns of abundance and occurrences of species.

4:3 AQUATIC ENVIRONMENTS OF THE SHORE ZONE AND COASTAL WATERSHED

4:3:1 Components of Coastal Regions

Two important components of coastal regions that need explaining are the coastal and shore zones.

Coastal Zone

Several definitions have been proposed to define the coastal zone but the main approaches relate to linear, administrative and biophysical criteria (Anonymous, 1980a). In general terms, the coastal zone includes all parts of a continent under maritime influence (Clark, 1977) extending seaward to the edge of the continental shelf (Ketchum, 1972).

A rational classification of the coastal zone has been developed in the United States where a Federal Government Act (Coastal Zone Management Act of 1972) recommended that the zone should be subdivided into the shore lands and coastal waters subsystems.

Aquatic environments of the shore lands, which are governed by the discharge of runoff water, include the coastal watersheds and floodplains (Clark, 1977). Lands that drain directly into coastal waters (greater than $0.5^{o}/oo$ salinity) are regarded as coastal watersheds whereas coastal floodplains are referred to as those lands draining directly into freshwater (less than $0.5^{o}/oo$ salinity). The penetration of coastal waters into estuarine basins is variable and herein refers to the position attained at mean high water on a spring tide (M.H.W.S.).

Clark (1977) divided the coastal waters subsystem into estuarine, nearshore and oceanic regimes with the nearshore regime delineated from the oceanic regime at a distance 3 nautical miles from the shore. In Australia, the coastal waters subsystem does not include Clark's oceanic regime

(Australian Coastal Waters Powers Act, 1980). This local use of the term 'coastal waters' will be adopted in future coastal management studies in Australia and has been applied in this study.

Shore Zone

The region where aquatic and terrestrial environments meet is regarded as the shore zone (*sensu* de Sylva, Kalber and Shuster, 1962). The functional upper boundary for the aquatic component of the shore zone in this study was taken as the position of M.H.W.S. for tidal systems. The lower limits were taken as either the position 50 m offshore from mean low water, spring (L.M.W.S.) or the 6 m depth level below L.M.W.S. Hence, the shore zone is large over shallow tidal flats and small on beaches that have steep profiles. Most Tasmanian estuaries form part of the shore zone.

The same limits apply to non-tidal bodies but the tidal positions are replaced by boundaries approximated from extreme low water levels. The shore zone is thus represented in the coastal zone by estuaries, marginal and marine environments.

4:3:2 Environmental Characteristics

Several environmental factors such as the geomorphology, weather and oceanic characteristics are likely to affect and determine conditions in the coastal zone. Because faunas are dependent on the complexity and stability of environments, the delineation of these parameters is an important prerequisite for biological investigations.

Major environmental features of the Tasmanian shore zone are discussed in this section.

Geomorphology

The major outlines of this complex coastline are of Tectonic origin (Davies, 1965) and its submergent and emergent features are due to fluctuations in sea level during the glacial and post-glacial periods (Edwards, 1941). The recent submerged coast demonstrates a wide array of geomorphological features; sea cliffs, shore platforms, reefs, islands, cuspate forelands, tombolos, spits, estuaries, bays, lagoons and beaches are all well represented.

Beach sediments, which are predominantly siliceous (Davies, 1965), are related to geomorphological processes that have operated during phases of climatic and sea level instability during the Quaternary (Bird, 1976). Shelf-derived calcite is also a major component of sands but its concentration is extremely variable between areas (Davies, 1972).

Drift of beach materials along the coast is in an eastward and northward direction from the South-West and the greatest density of beaches is in the northeastern sector (Davies, 1965). Storm Bay, Oyster Bay and Perkins Bay are regarded as major sediment traps.

Estuarine sediment types are controlled by the bedrock types in upstream erosional zones and site deposition within the system. Consequently, variation in sediment characteristics within an estuary, as well as between nearby estuaries, is often quite evident. Larger systems, such as Macquarie Harbour, can exhibit extreme contrasts of sediments due to local erosion of bedrock. In such areas large fetches facilitate wave erosion, and the transport of sediments is reduced by lower current speeds. Deposition of marine sediments is evident in the lower reaches of most estuaries and beaches in the vicinity of rivers with quartz-rich, high runoff catchments such as those in the north, south and west are actively being replenished with fluvial sediments.

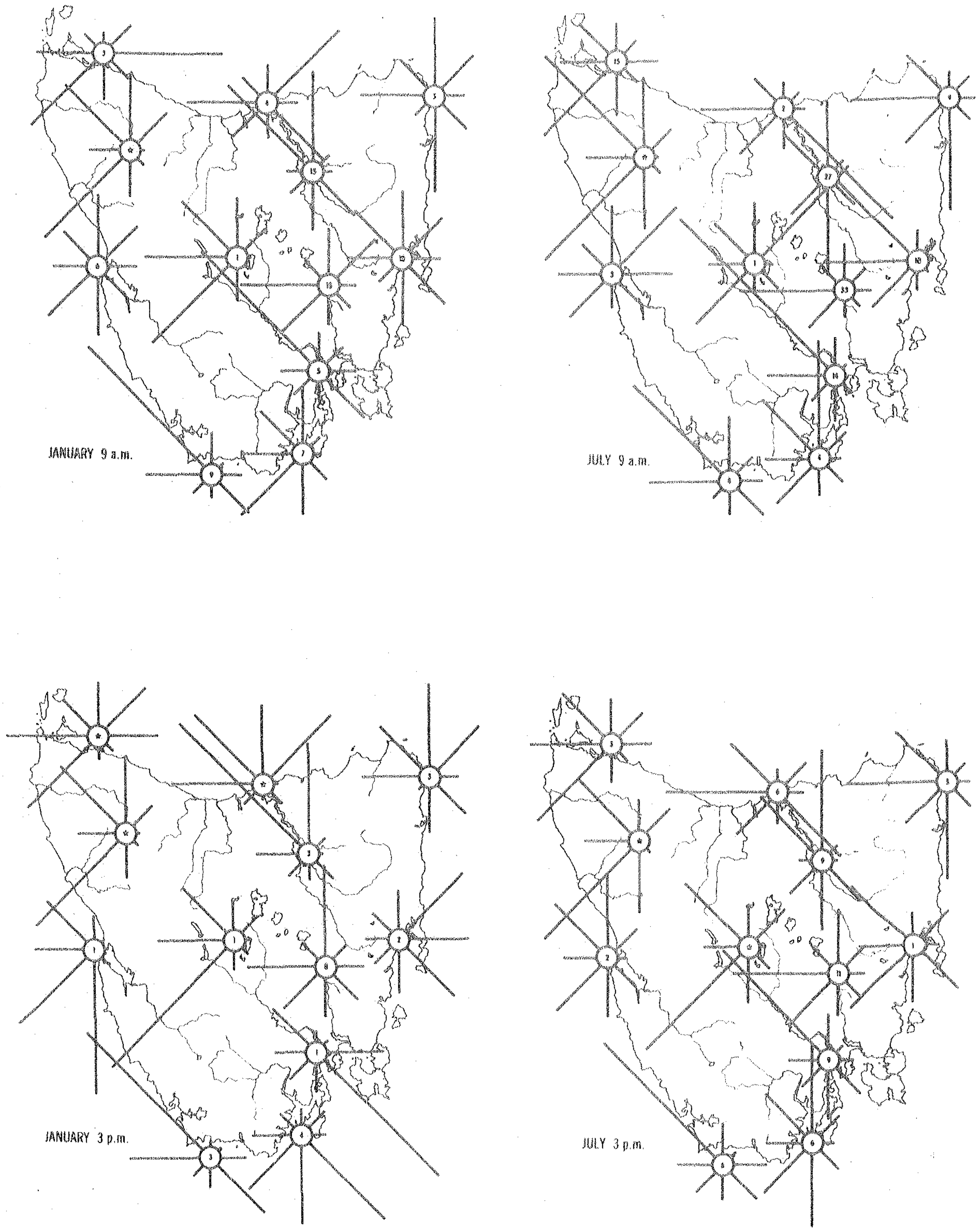


Fig. 4:2. Mean wind directions in Tasmania for January and July at 9 a.m. and 3 p.m.. Figures in circles indicate the mean number of recorded calms - where an asterisk occurs no observations are available (from Langford, 1965).

Meteorological Factors

Weather is an important factor influencing environments of the shore zone. Winds and pressure gradients affect wave climates, tidal patterns, turbidities, temperatures and the distribution and amount of freshwater runoff.

The Tasmanian climate, best described as temperate maritime, is dominated by anticyclonic circulations in summer and cyclonic circulations in winter (Coleman, 1981). These systems are continuously evolving and produce vital seasonal climatic variations which are associated with the variability in strength and occurrence of the prevailing westerly winds (Langford, 1965).

On the West Coast, the westerlies, which are directed mainly from the north-west in the south and from the south-west in the north, reach their greatest strength and persistance in winter and spring. These winds are responsible for the almost continuous swells experienced along the West and South Coasts. In summer, winds are directionally more variable and extended periods of northeasterly and southeasterly winds are not uncommon (Fig. 4:2).

The rainfall distribution is important in determining the salinity characteristics of estuarine systems in each area. While much of Australia is arid, in contrast, about three-quarters of Tasmania receives more than 750 mm of rainfall a year (Gentilli, 1977). Highest annual means are recorded from the West and Central Highlands, where one station, Lake Margaret, averages 3,700 mm per annum (Commonwealth Bureau of Meteorology records). In comparison, the East Coast is drier and much of the shorelands receive on average less than 500mm per annum.

Extreme air temperatures are important in controlling water temperatures in shallow estuaries and over tidal flats. Mean extreme coastal air temperatures vary from 3 - 7°C in winter to 17 - 23°C in summer (Fig. 4:3).

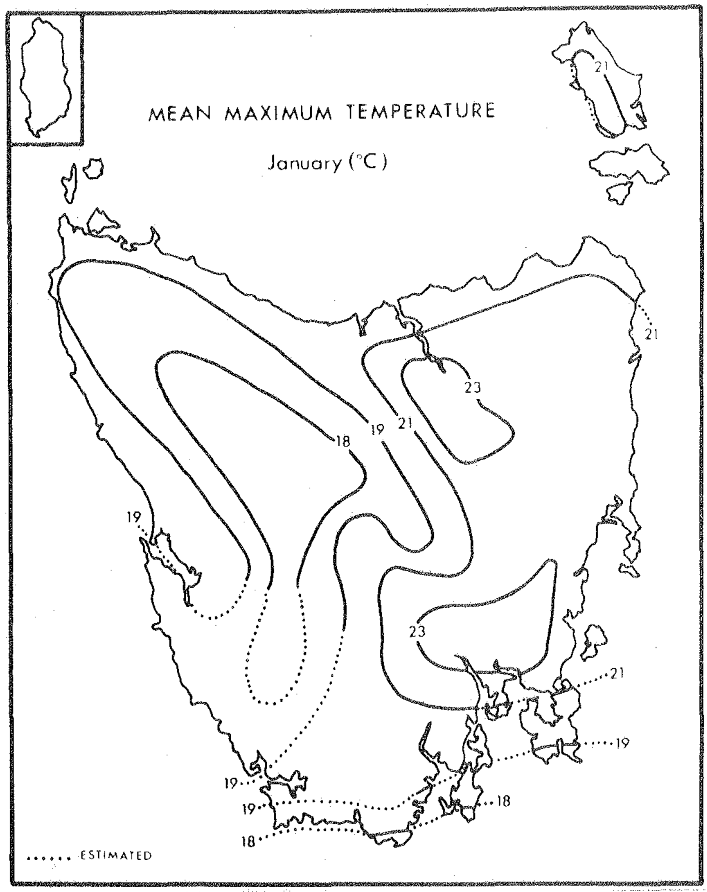
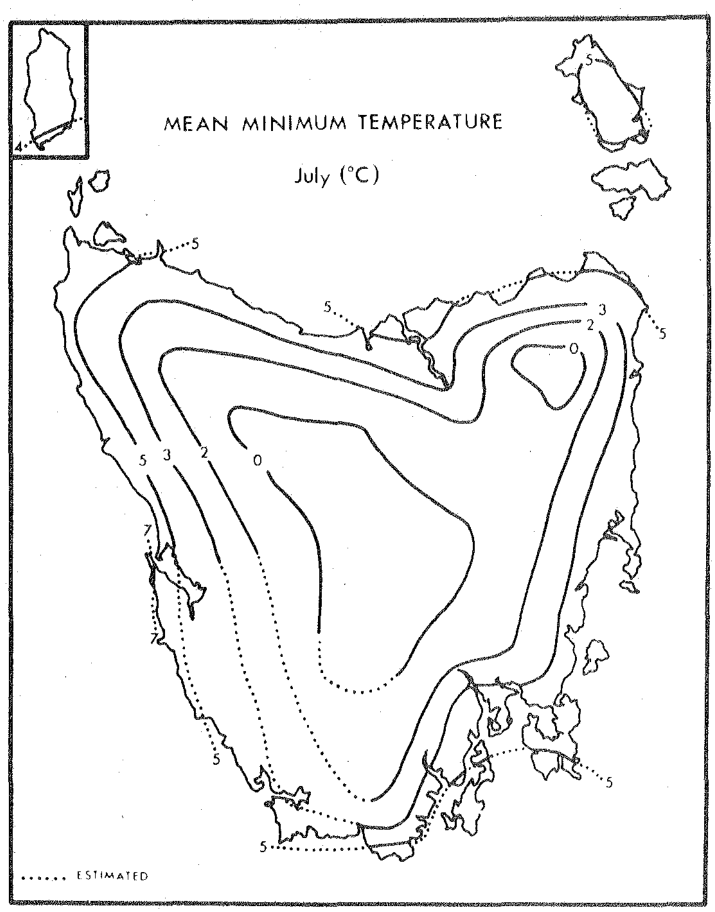


Fig. 4:3. Mean maximum and minimum air temperatures for Tasmania in January and July respectively (from Anonymous, 1979).



Water Masses and Circulation

Knowledge of the water masses and their movements in much of the Tasmanian region, particularly in the southwestern sector (Matthews, 1978), is largely of a hypothetical nature. Studies by Vaux and Olsen (1961) and Godfrey, Jones, Maxwell and Scott (1980) discussed circulation in Bass Strait while Rochford (1957, 58, 59a, 77), Wyrtki (1960), Hamon (1965), Hamon and Kerr (1968), Boland and Hamon (1970), Newell (1974), Cresswell and Wood (1977), Cresswell and Golding (1979), Hamon and Golding (1980) and others have contributed to the knowledge of circulation patterns in the Tasman Sea. The following summary of the activities of surface water masses in this region (Fig. 4:4) was taken from Rochford (1974).

Sea characteristics in summer appear to be maintained by 3 water masses: (1) a complex carried southward by the East Australian Current and eddies; (2) high salinity water carried westward and southward into the Tasman Sea from the Central South Pacific; and (3) upwellings from subsurface penetrations of subantarctic waters. In the Tasman Sea these patterns, however, are largely controlled by the presence of anticyclonic mesoscale warm core eddies (Scott, 1978). While these eddies can affect conditions in the shore zone of New South Wales, their impact on Tasmanian coastal environments is not yet known.

In general, coastal waters are derived from the same water mass mixtures as offshore waters (Rochford, 1974), however they have lower temperatures and salinities because of dilution by estuarine waters. Coasta marine faunal compositions, nevertheless, are generally coincident with the distribution of water masses (Pielou, 1979).

In winter, control of hydrological conditions is maintained by all the above water masses and an eastward drifting mass, the Bass Strait water. Subtropical water masses dominate the surface in this area although the biological effects of subantarctic intrusions have been demonstrated (Taw, 1973; Taw and Ritz, 1979).

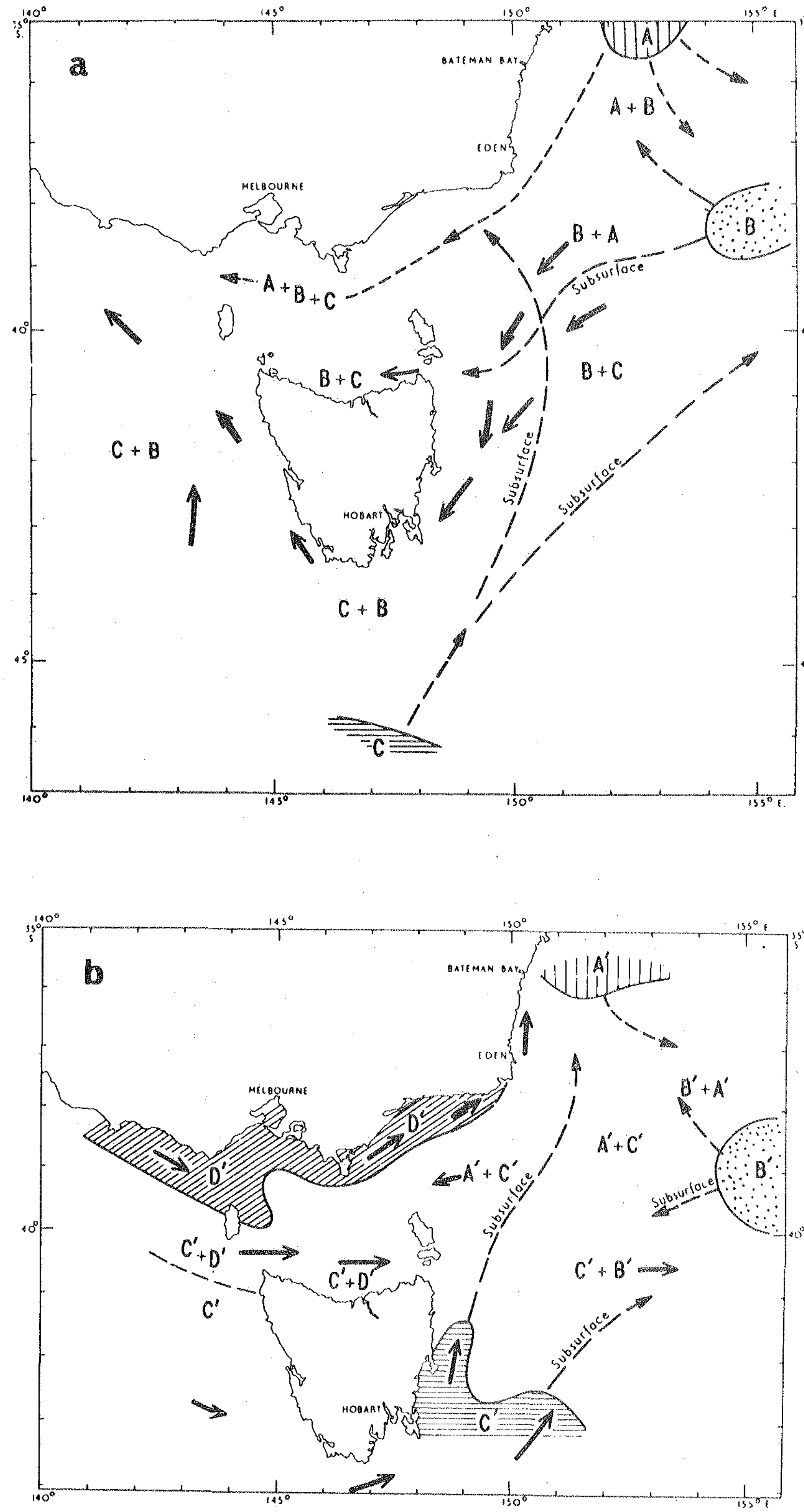


Fig. 4:4. Surface water masses and their mixtures in (a) summer and (b) winter. A,A' East Australian current water. B,B' Central Tasman water. C,C' Sub Antarctic water. D' Bass Strait water. (from Rochford, 1974).

Tides are mainly semi-diurnal but the tidal magnitude is variable around the island. In comparison with other regions which are microtidal, Bass strait is typically mesotidal and tidal ranges exceeding 3.3 m have been recorded. Some microtidal areas, such as Macquarie Harbour, appear to be more influenced by barometric pressure than non-meteorological factors (J. Matthews, personal communication).

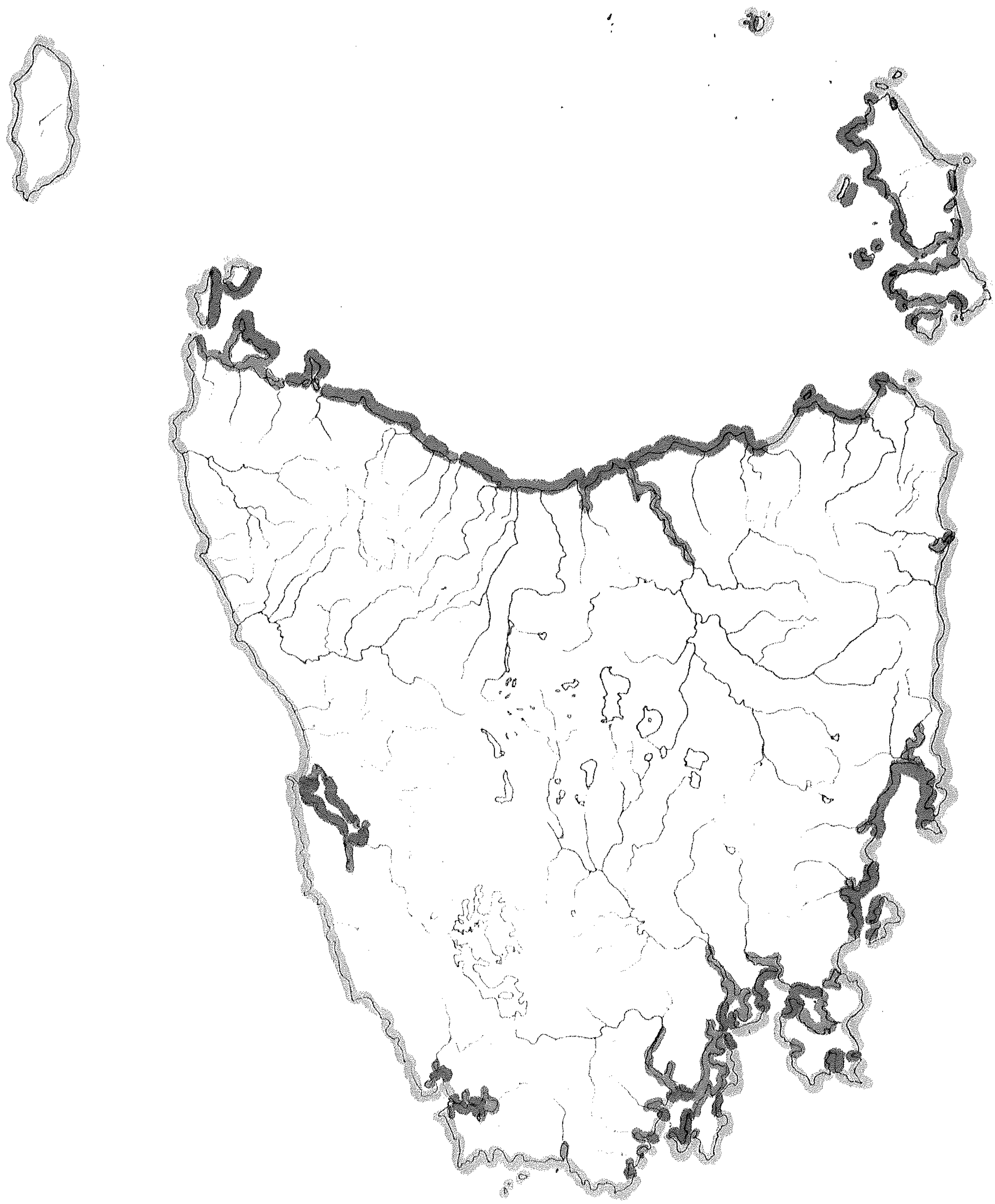
Other areas of the coast, particularly bays, are also considerably affected by strong winds. Onshore gales can cause tides to remain at high levels for long periods and at Fremantle, Western Australia, where this phenomenon has been monitored, these levels have been maintained for almost 6 days (Anonymous, 1980b). Similarly, strong offshore winds can depress tidal levels.

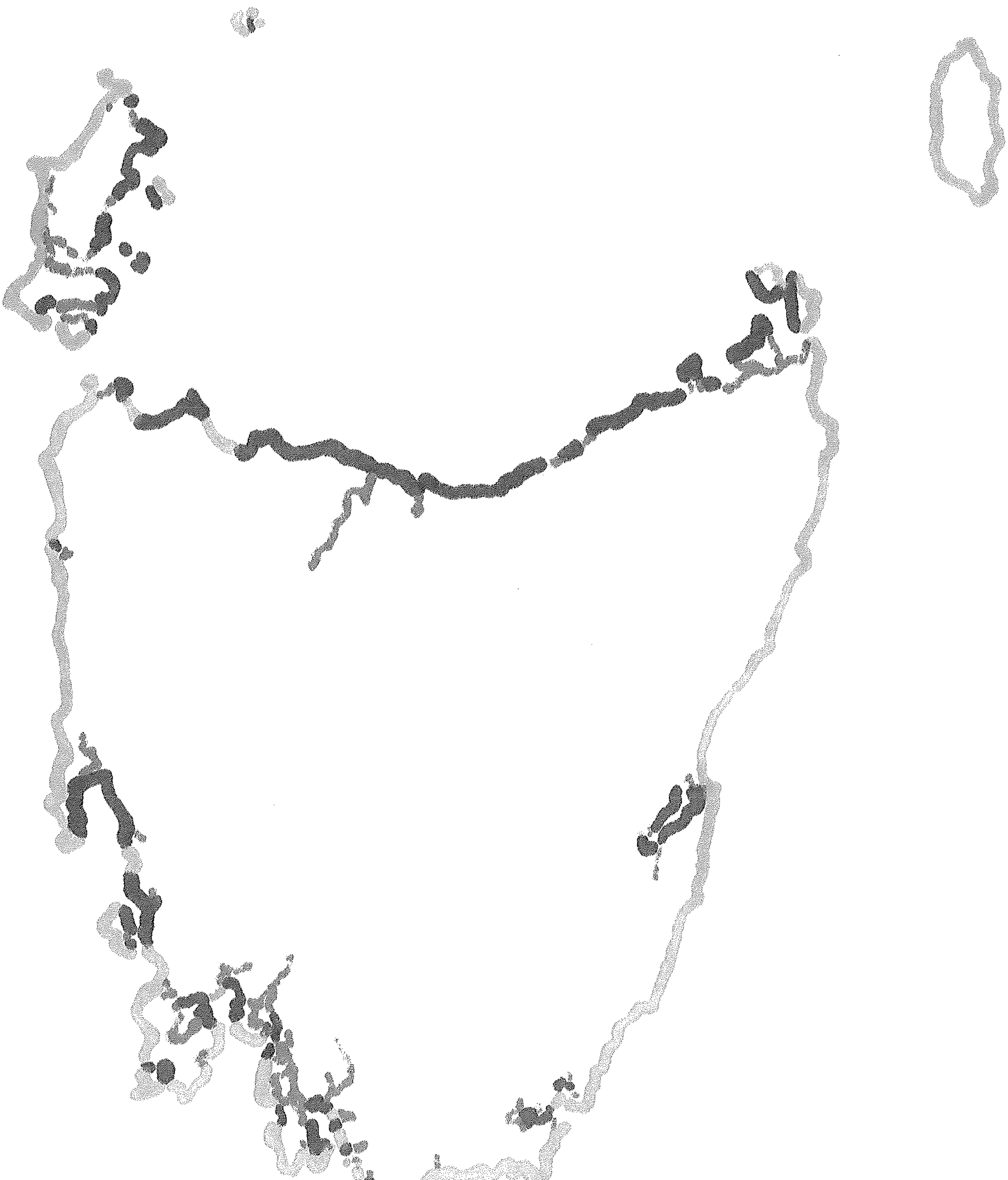
Wave Action

Sea and swell conditions have been compiled by the Bureau of Meteorology from 13 stations around Tasmania (Coleman, 1981). These records are based on standard hindcasting techniques and provide daily information and mean values for these variables at 0900 and 1500 hours over 4 - 13 years. The duration varies for each station. The more exposed stations, such as Cape Sorell, do provide useful information on sea conditions but some recording stations are situated in bays and may not be representative of conditions along the adjacent coastline.

The West and South Coasts receive large, almost continuous, swells from the south-west (Davies, 1965). Seas are usually moderate to rough and wave heights sometimes exceed 9 m. In comparison, exposed coasts in the east and north are lower energy and experience a higher frequency of seas that are smooth or slight. Swells in Bass Strait are quickly dissipated by strong tides and shallow water.

Fig. 4:5. Levels of exposure of the Tasmanian shore zone. Sheltered, semi-exposed and exposed coastal sections are designated by red, blue and green areas respectively.





Promontories and islands act as barriers and reduce wave activity and fetches in some areas. The largest extensions of sheltered areas are in the north-west, around Freycinet Peninsula and the Furneaux Group, and along the ria coasts of Port Davey and southeastern Tasmania.

The wave exposure characteristics of the Tasmanian region are illustrated in Figure 4:5.

Water Temperature

Distributions of surface temperatures of oceanic water in the Tasmanian region have been presented by Newell (1960), Vaux (1970), Rochford (1974) and Edwards (1979), whilst information on the shore zone was collected during the course of this study.

Edwards (1979) has provided evidence to suggest that coastal zone waters are influenced by an insurgence from the north-east of warmer subtropical water from the East Australian Current (Fig. 4:6). The highest mean temperature occurred in March when oceanic water in the northeastern sector exceeded 19^{o}C; in the south this temperature was less than 18^{o}C. Mean winter temperatures, obtained in September, were 12^{o}C and 13^{o}C in the south and north respectively.

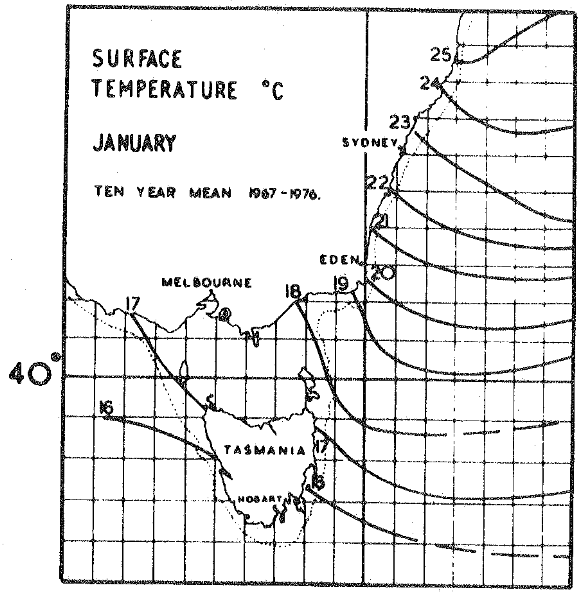
Shallow areas of estuaries and bays are subjected to much greater extremes of temperature. The surfaces of some small closed brackish systems froze in winter, while maximum temperatures of 30.4^{o}C were recorded in summer.

Vegetation

The flora of the shore zone is dominated by macrophytic plants and algae. Aquatic plants are represented by brackish and freshwater species and a few monocotyledons, the seagrasses, also live in marine conditions.

Vegetation is densest in shallow sheltered areas where light levels are optimal and wave energy is low. Attachment is rendered more difficult

Fig. 4:6. Mean surface water temperatures in southeastern Australia between 1967 and 1976 (adapted from Edwards, 1979).


SURFACE
TEMPERATURE °C
JANUARY
TEN YEAR MEAN 1967-1976.
SYDNEY
EDEN
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TASMANIA
HOBART
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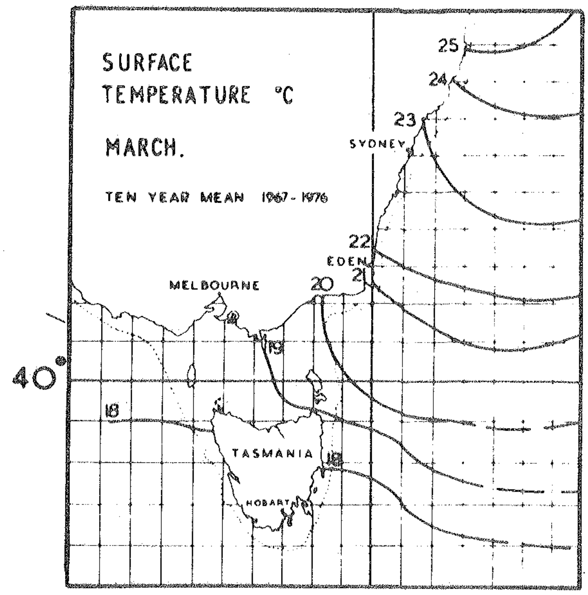
SURFACE
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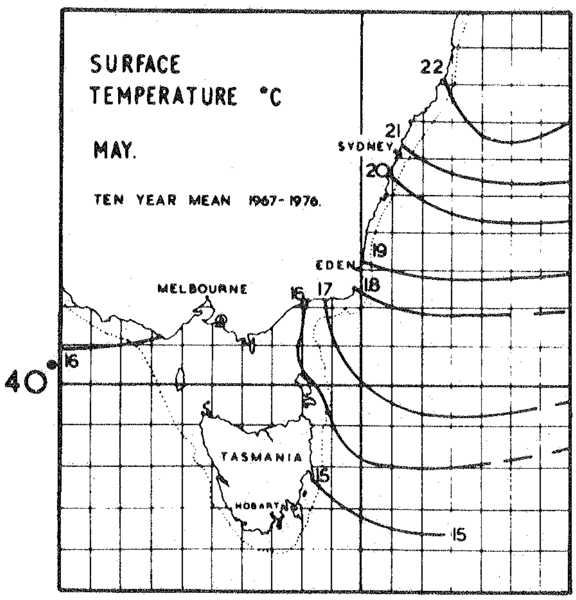
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MAY.
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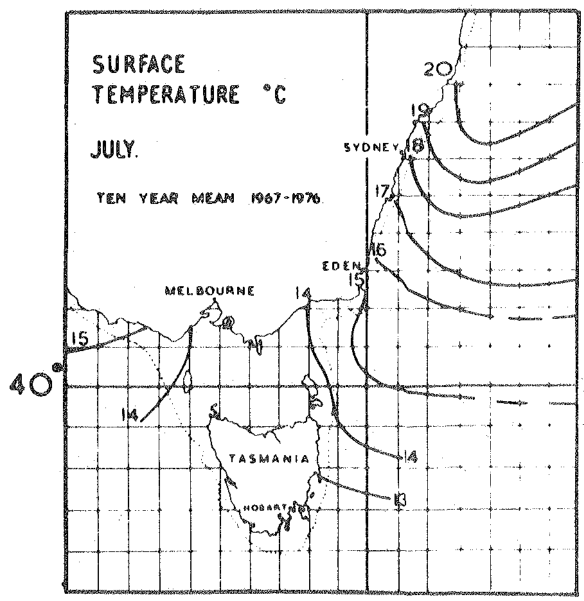
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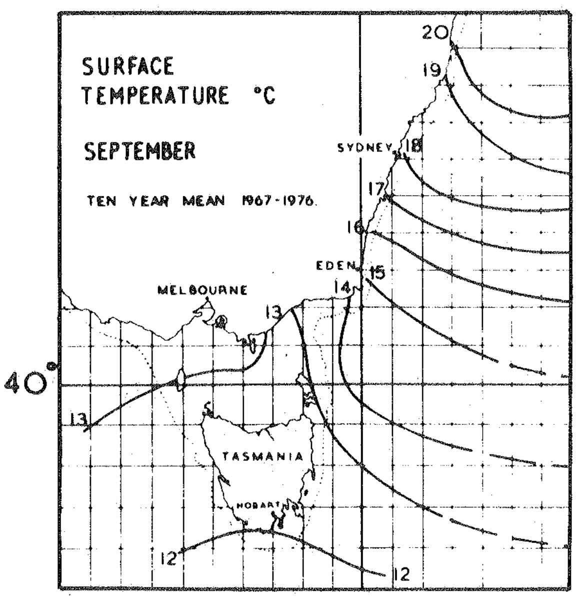
SURFACE
TEMPERATURE °C
SEPTEMBER
TEN YEAR MEAN 1967-1976.
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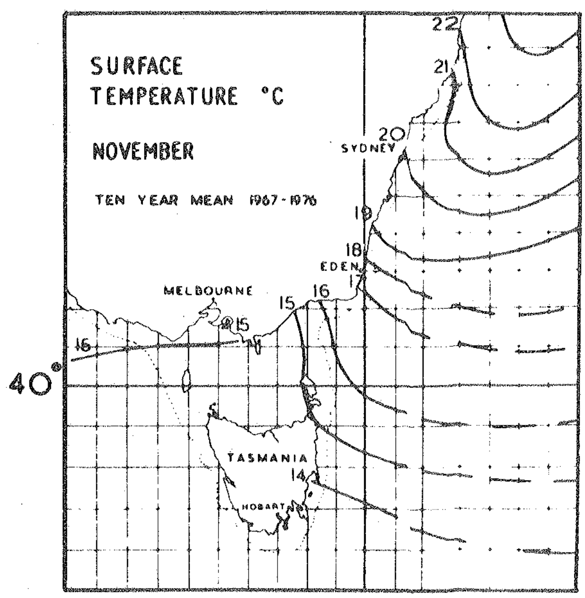
SURFACE
TEMPERATURE °C
NOVEMBER
TEN YEAR MEAN 1967-1976
SYDNEY
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on open coasts where the vegetation generally consists solely of uprooted plants from nearby sheltered zones or detached algae, particularly kelps, from offshore and reef areas. In estuarine systems, the greatest biomass of vegetation occurs along the South-East Coast and the East Coast. Combinations of poorly compacted sediments,high current speeds and low average water transparencies may retard subtidal growth of vegetation in other areas. In fact, seagrasses appear to be totally absent from some estuaries (e.g. Piper and Pieman Rivers).

The distributions of most southern Australian macrophytes, including seagrasses, are poorly known. *Ruppia maritima* is the dominant plant in brackish environments while *Lepilaena* spp. and *Potamogeton* spp. are also abundant. The most extensive beds of *Ruppia* occur along the East Coast in closed estuaries and in the sheltered upper areas of open estuaries. Stands of *Zostera muelleri* are dominant in the lower reaches of open systems. *Heterozostera tasmanica* also penetrates into estuaries (Aston, 1973) but in Tasmania it is most common in sheltered marine habitats, particularly in southeastern Tasmania, where it forms huge stands in shallow bays.

In Bass Strait 3 other seagrasses, *Posidonia australis, Amphibolis antarctica* and *Halophila ovalis,* are significantly abundant in subtidal marine areas, although they also co-exist in the lower reaches of the Tamar River Estuary. *Posidonia* appears to be limited to Bass Strait where, as in many other parts of Australia, it is the dominant infralittoral marine species. *Halophila* also occurs as widely distributed but low density stands in D'Entrecasteaux Channel and, although Ducker *et al.* (1977) listed Bass Strait as the southern distributional limit of *Amphibolis,* small beds have been observed off Maria Island (Edgar, 1981). The mangrove, *Avicennia marina,* although recorded from southern Victoria (Shapiro, 1975), does not occur in Tasmania.

Macrophytic algae is mainly represented in seagrass habitats by epiphytes. This flora, represented mainly by rhodophytes, is very diverse (Ducker *et al.*, 1977) and many of the component species were difficult to identify.

Benthic algal communities are best developed in sheltered marine bays and brackish areas where chlorophytes are often abundant. *Enteromorpha* sp. is common in estuaries, particularly in areas enriched by nutrients.

Phaeophytes are mostly represented in sedimentary environments as algal drift. During storms the major reef species, *Macrocystis pyrifera, Durvillea potatorum* and *Cystophora* spp., may become detached and washed onto beaches forming temporary, but complex, habitats. When washed into closed estuaries, they become an important nutrient source and can, on occasions, completely choke small estuaries by restricting water flow. Their subsequent decomposition may result in de-oxygenation and acidification of the affected system.

4:3:3 Classification of Environments

Sedimentary environments of the Tasmanian shore zone consist of 3 basic types, each of which is recognisable on geomorphological grounds. The environments of this proposed classification can be further subdivided using other physical attributes (Fig. 4:7). These are outlined below.

Closed or Semi-closed Drainage Systems (Fig. 4:8)

These systems consist of estuarine and freshwater basins of the coastal watershed separated from the sea by barriers, dunes or beaches. Typically, they are not connected to the sea by deep channels but some larger systems are open for short periods by channels formed by man's activities, flooding or storm waves. Others are seasonally connected to the marine environment by very shallow overflow channels. The extent of closure depends on such

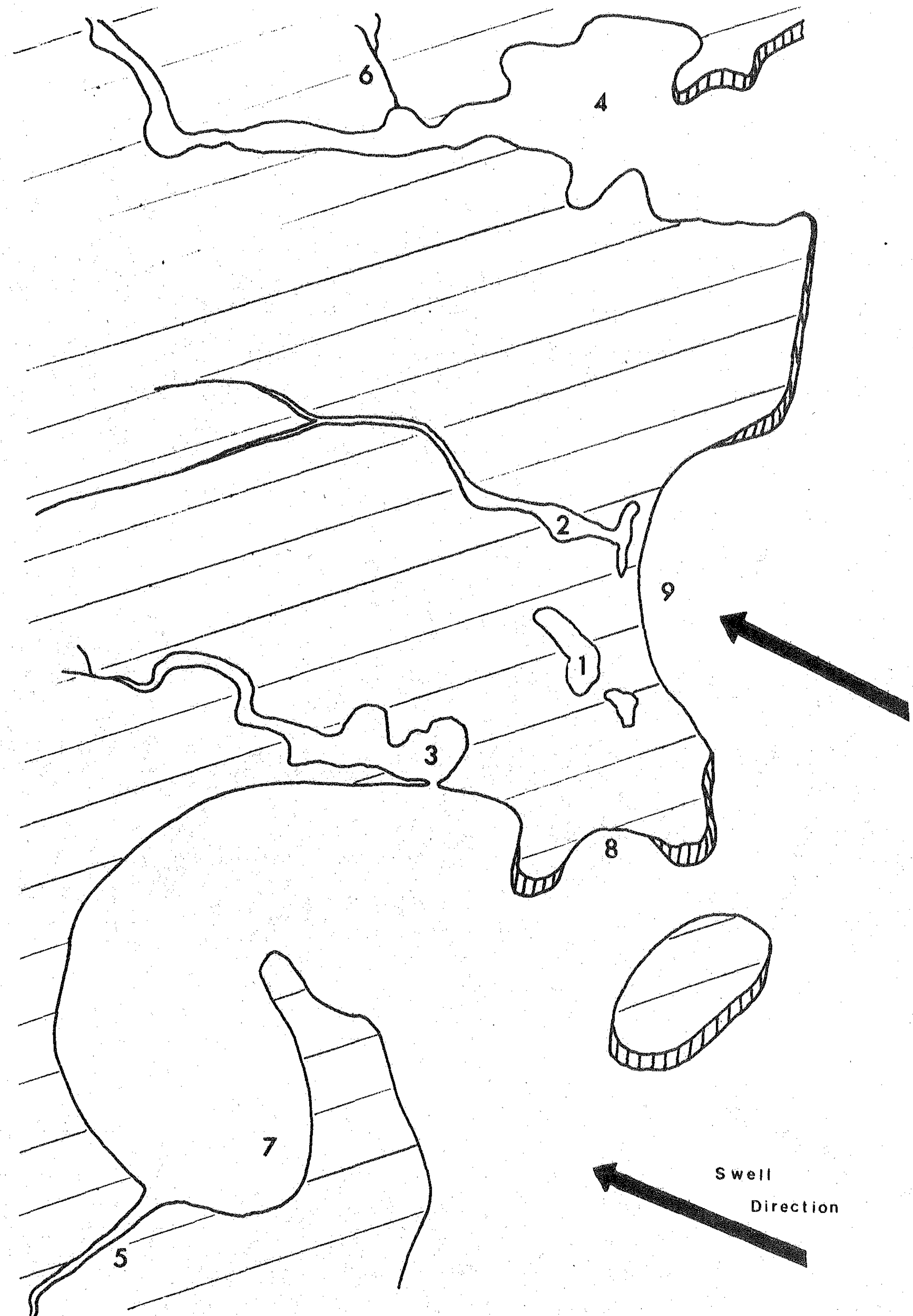


Fig. 4:7. Diagrammatic representation of types of sedimentary habitats found in the Tasmanian shore zone and coastal watershed. Closed and semi-closed drainage systems: 1. coastal lake; 2. beach-dammed river. Open drainage systems: 3. open lagoon; 4. bay-estuary; 5. tidal river; 6. tidal tributary. Beach systems: 7. sheltered beach; 8. semi-exposed beach; 9. exposed beach.

environmental factors as geology, wave exposure, tidal range and the amount of freshwater entering the system. Consequently, there is a general gradation from permanently closed to permanently open systems which fluctuates with time.

In Tasmania, this group can be divided into (1) coastal lakes, (2) bar-dammed rivers and lagoons and (3) beach-dammed rivers. These categories were modified from an unpublished study by B. Mollison.

Coastal lakes

These consist of basins, such as saltpans and dune lakes, which are not connected with other systems.

Saltpans are shallow basins which, during summer and early autumn, become hypersaline and in extreme conditions can become saltflats. They are most concentrated on the east coast of Flinders Island; Little Sandy Lagoon, Big Sandy Lagoon and Chain Lagoon are typical examples.

Dune lakes have been classified into several categories (Jennings, 1957), however, collectively they are hollows in the dune topography passing beneath the water table (Bird, 1976). As such, they have low salinities or are freshwater. Many are permanent (e.g. Lake Flanagan, Blackmans Lagoon and Lake Martha Lavinia) but others dry out seasonally (e.g. Semaphore Hill Lagoon, Trousers Lagoon and Windmill Lagoon).

Bar-dammed lagoons and rivers

These are estuarine systems closed by barrier beaches and are characterised by a predominance of brackish conditions. Systems in areas of low intermittent rainfall, such as those along the East Coast, are typical.

Bar-dammed lagoons are generally deep and have most of their volume below the mean tide level. As a result of salt wash over the berm at high tide, particularly during heavy seas, the salinities of these systems can increase during the period of closure. Some lagoons remain closed for several years and only open after extreme flooding or during storms. These systems are usually highly productive and the shallow sections contain extensive areas of macrophytes; Cameron Inlet, Kelvedon Lagoon, Big Lagoon and Diana's Basin are typical.

Some narrow river estuaries are open by shallow channels only at high tide but are seldom totally closed. These systems often have well developed salt wedges. The Scamander and Denison Rivers are typical bar-dammed rivers.

Beach-dammed rivers

These are small rivers and creeks approaching sandy coasts which have their flow blocked by extensive beaches. They are typically freshwater or low salinity systems and are rarely stratified. The head of water is often large and this leads to the formation of arms of water running parallel to the beach behind the berm. In these situation, river water passes to the sea via seepage channels. The form of the lower basin and the associated seepage channels are constantly modified by flooding, and marine and wind deposition of sediments. These systems may open during floods due to heavy rainfall in the catchment area. During this period, which is usually short, saltwater can enter the system via the relief channel if sea storms are coincident.

The smaller rivers of the West and South Coasts are typical beach-dammed rivers and show afffinities with tidal rivers in the same area. Specific examples are the Nelson and Thornton Rivers and Stiffy's Creek.

Open Drainage Systems (Fig. 4:9)

These are estuarine systems permanently connected to the sea or other non-closed water basins by a channel. In Tasmanian systems, channel widths range from only a few metres to in excess of 5 km. Similarly, depths range

Fig. 4:8. Closed estuarine system: Seven Mile Beach, South-eastern Tasmania.

Fig. 4:9. Open estuarine system: Douglas River, Eastern Tasmania

from 1 cm to approximately 50 m. The size, depth, shape and flow characteristics of these systems are equally variable. Most basins are brackish but some systems with rocky substrates near their entrances have riffle zones at the sea.

In this region open estuaries occur in three often interrelated forms. These are as follows: (1) open lagoons; (2) bay-estuaries; (3) tidal rivers and creeks.

Open lagoons

These lagoons remain open to the sea all year round. Permanent channels, shallower than 4 m deep, persist between barriers that are usually extensive. With only a few exceptions, they consist of the largest lagoons and are probably intermediate in form between closed lagoons and the following category. The Great Swanport, Pittwater, Musselroe Bay and North East River are typical examples.

Bay estuaries

These systems include river estuaries with wide extensions or embayments and incorporate most of the major estuarine complexes. Most possess an array of tidal channels surrounded by extensive shallow areas which become mudflats and sandflats at low tide. These flats are best developed in Bass Strait systems (e.g. Tamar River, Port Sorell and Mersey River) which are mesotidal and least developed on the West Coast (i.e. Macquarie Harbour and Port Davey) where tidal ranges are smaller.

Estuaries of the Derwent and Huon Rivers also fit this category.

Tidal rivers, creeks and tributaries

These are river estuaries, permanently connected to other estuarine systems or the sea, that mostly lack widened sections and embayments. Surface salinities are usually freshwater or oligohaline at the sea although

Fig. 4:10. Sheltered beach: Stewarts Bay, South-eastern Tasmania.

Fig. 4:11. Exposed beach: Dianas Beach, Eastern Tasmania.

deeper systems can have well developed salt wedges. They are generally less productive than similarly proportioned estuarine bays and lagoons. High flow coefficients, particularly in larger West Coast systems, produce extensive marginal zones in nearby coastal areas for much of the year.

The largest systems are concentrated on the West Coast and include the Davey, Arthur and Pieman Rivers. Several medium sized river estuaries along the North Coast (e.g. Forth River, Black River, Emu River) and a few small freshwater creeks (e.g. Buttons Creek, Cray Creek, Iron Creek) also fit this category.

Creeks which are influenced by tidal flow and join larger estuaries but not the sea are known as tidal tributaries (e.g. Risdon Creek, Sorell Rivulet).

Beach Systems

Beach habitats are usually categorised according to various levels of exposure. The system used herein follows Guiler (1952) in which 3 levels were recognised. These are (1) sheltered, (2) semi-exposed and (3) exposed beaches.

Sheltered beaches (Fig. 4:10)

These beaches are enclosed within marine inlets or bays or are situated in the lee of islands or reefs. They are typically shallow areas with small fetches and generally experience low wave energy exposure. In some areas they form extensive intertidal flats with prominent ridges and runnels. Their subtidal areas are mostly densely vegetated with seagrasses and macrophytic algae. Some sheltered beaches are influenced by the floodwaters of nearby estuaries but most are predominantly marine.

The most extensive areas occur along the ria coast of the South-East, and in the protected channels and embayments of the Furneaux Group and the far North-West.

Semi-exposed beaches

These beaches are more exposed than sheltered areas and receive moderate wave action on a sporadic basis. Areas of exposed coasts that are partly protected from direct wave action by headlands, shallow reefs or beds of macroalgae (i.e. *Macrocystis*) are included. At the opposite end of the scale, partly protected or enclosed beaches that receive swells from wave reflection or have long fetches facing the prevailing winds also fit this category. These habitats are normally less productive than sheltered beach habitats because the attachment of macrophytes is hindered by wave action.

This category is best represented in southeastern Tasmania and along much of the Bass Strait coastline.

Exposed beaches (Fig. 4:11)

These beaches are exposed to the direct energy of oceanic waves. On the West and South Coasts, where swells are heavy and almost continuous, ridges and runnels do not form and swash zones are long and smooth. Exposed beaches on the East Coast receive equally large swells but these are much less frequent and periods of calm are not uncommon. In Bass Strait some beaches facing west are typically exposed but experience less continuous and intense swells than other exposed coasts because waves are partly dissipated by the shallow water and strong tides.

4:3:4 Distribution of Environments

The coast of Tasmania and its neighbouring islands (excluding Macquarie Island) was divided into 16 convenient but subjectively determined coastal regions (Fig. 4:12). Habitat types represented in the above classification are not evenly distributed around Tasmania so a breakdown

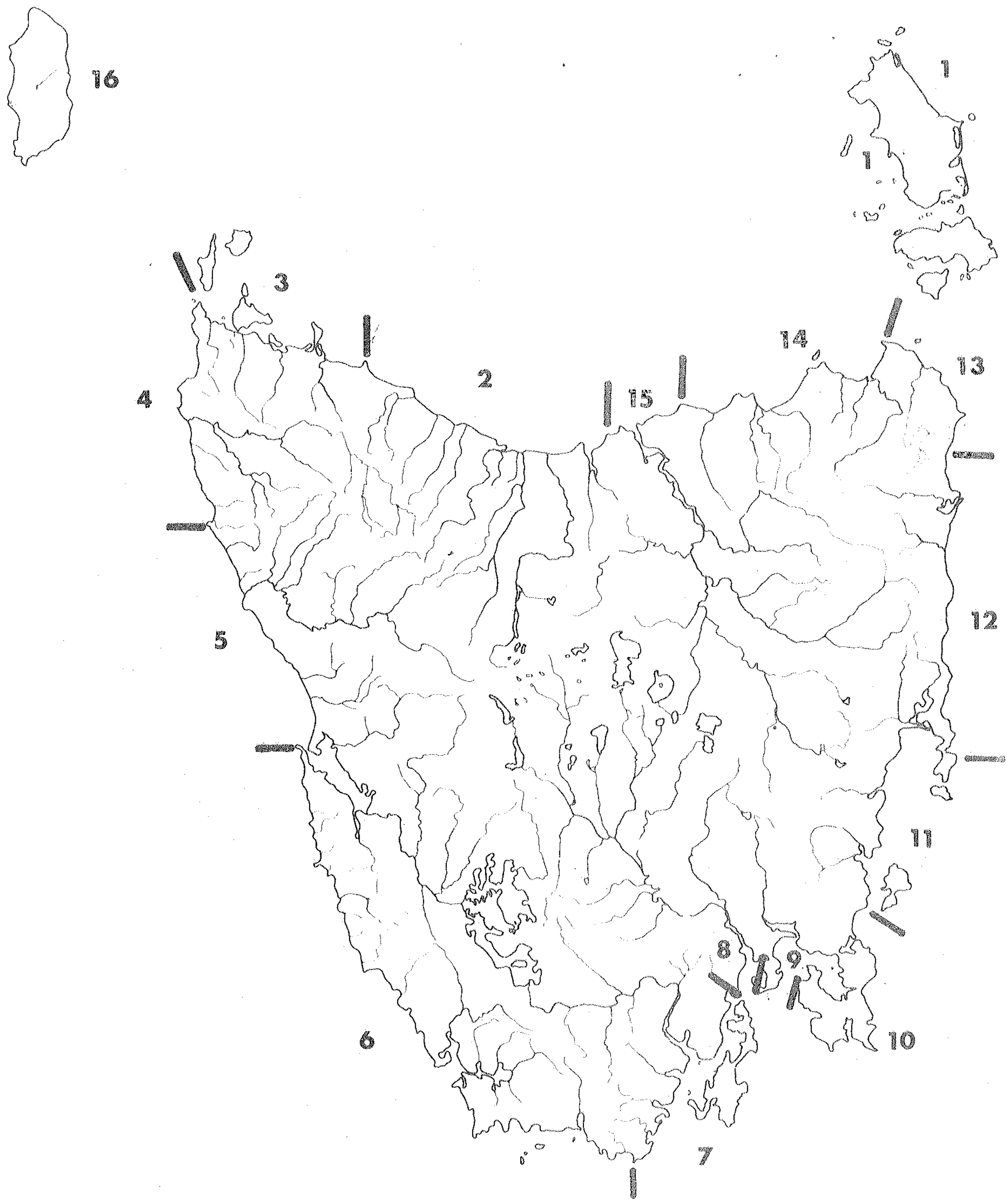


Fig. 4:12. Boundaries for the 16 coastal regions discussed in the study

of the coast into smaller areas was necessary to permit the main features to be highlighted on a regional basis.

(1) Furneaux Group

This region includes the group of islands in eastern Bass Strait dominated by Flinders and Cape Barren Islands and extends south to Clarke Island. The Kent Group is also included.

The shore zones of the Kent Group and much of the west coasts of major islands are rocky. Existing beaches are sheltered or semi-exposed, the extent of each depending on the protection offerred from offshore seagrass beds and reefs. Franklin Sound and Armstrong Bay form extensive sheltered marine areas with large stands of seagrasses.

The west coasts of the largest islands are drained by a few small rivers and creeks but the greatest development of estuarine systems is located on the east coasts. A series of lagoons, dune lakes and saltpans have formed behind the exposed sandy coasts. Some, such as Sellars Lagoon, Cameron Inlet and Logan Lagoon, form large closed of semi-closed systems and only North-East Lagoon can be regarded as a true open lagoon.

(2) North Coast

Extending from Badgers Head to Rocky Cape, this region is characterised by small sheltered and semi-exposed beaches between rocky headlands in the west and the longer, more exposed beaches to the east. Estuaries are abundant and, except for the two largest systems, the Mersey and Rubicon-Franklin Rivers, most are tidal rivers and creeks that experience large freshwater runoffs. Coastal lakes larger than small farm dams are absent from this area.

(3) Western North Coast

This region extends from Rocky Cape to Cape Grim and north to Three Hummock Island and is characterised by the presence of extensive sheltered marine areas.

Complex reticulating channels drain several large marine embayments which have widespread developments of seagrass beds and sandflats. Most have prominent bars which, in contrast to the closed estuarine systems of the Furneaux Group, probably remain open because of less wave exposure and faster tidal currents.

Duck Bay is basically estuarine but Robbins Passage, although receiving runoff from the Montagu River,has marine characteristics. Other embayments, such as East Inlet and Mosquito Inlet, have virtually no freshwater intake and are typical tidal arms or enclosed sheltered beaches.

Western areas contain a few small dune lakes whereas the few exposed beaches are restricted to small areas of the western coasts of Hunter and Three Hummock Islands and the western side of Woolnorth Point.

(4) Northern West Coast

This region extends from Cape Grim to Sandy Cape and is essentially a series of long exposed beaches between rocky headlands. Smaller, less exposed beaches exist on the headlands behind protective rocky outcrops but sheltered beaches are notably absent.

The Arthur, a tidal river, is the dominant estuarine system and the only one permanently open. Several small freshwater rivers and creeks reach the coast but, with the possible exception of the Nelson, Thornton and Pedder Rivers, most remain beach-dammed throughout the year.

(5) West Coast

The region from Sandy Cape to Cape Sorell contains large sections of exposed beach and includes Ocean Beach, the longest unbroken beach on the Tasmanian mainland, which extends for more than 25 km. The dominant feature is Macquarie Harbour, a large estuarine bay that receives runoff from the King and Gordon-Franklin River systems. It is generally oligohaline to a depth of several metres (J. Matthews, personal communication).

Coastal creeks and rivers are similar in characteristics to those in adjacent areas; the Pieman River is the largest tidal tiver. Coastal lakes are common in the dunes behind Ocean Beach.

(6) South-West Coast

The region from Cape Sorell to South-East Cape is large and least accessible for sampling. Beaches cover a smaller area than in other regions and most offshore islands lack beaches altogether. Most beaches are exposed, although some around Port Davey are partly protected and those in the tidal arms of Kelly Basin and Hannant Inlet are sheltered.

Most rivers and creeks entering coastal beaches are dammed but those entering rocky coasts, such as the Lewis and Mainwaring Rivers, are permanently open. Few lagoons are found in this area; New River Lagoon is the largest.

Port Davey, a large marginal zone influenced by runoff from the Davey River and the numerous smaller drainages of Bathurst Harbour, is a complex area in terms of habitats.

(7) D'Entrecasteaux Channel

The coastline from South-East Cape north to Piersons Point including Bruny Island is extremely diverse in the numbers and sizes of habitats.

Bruny Island acts as a large natural barrier to wave action so beaches along D'Entrecasteaux Channel are mostly sheltered. Because of this protection from ocean swells, flood waters from the Huon River are slowly entrained, hence the Channel sometimes acts as a weak marginal zone. Smaller embayments such as Port Esperance, Port Cygnet and Southport act as stronger marginal zones.

Sheltered bays, the lower parts of estuaries and Southport Lagoon, (a large tidal arm) have extensive beds of seagrasses. Most bays are shallow and form wide tidal flats at low tide. The few oceanic beaches on the east and south coasts of Bruny Island and the southern mainland are exposed or semi-exposed.

(8) Derwent Estuary

This region, which includes Ralphs Bay, encompasses the Derwent River and Estuary between Piersons Point and the Iron Pot.

Beaches near the entrance are typically semi-exposed whereas those in Ralphs Bay are sheltered. The main channel of the estuary is bordered by a number of smaller estuarine bays which have only minor developments of seagrasses.

(9) South-East Bays

This area extends east of the Iron Pot to North-West Head and includes Frederick Henry and Norfolk Bays; Denison Canal at Dunalley forms an internal boundary with the Peninsular regions.

This shore, although exposed in the southern sector, consists of a series of large semi-exposed and sheltered beaches between small rocky points. These beaches from large tidal flats with an extensive coverage of seagrasses, particularly in Norfolk Bay and Pipe Clay Lagoon.

The dominant estuary is a large open lagoon at Pittwater which receives runoff from the Coal, Iron, Orielton and Sorell Rivers. Apart from a bay estuarine system, the Carlton River, estuaries are restricted to beach-dammed rivers and tidal rivers. Dune lakes are abundant near the coast.

(10) Peninsula

This area extends south from North-West Head, around Tasman Peninsula, then north to Cape Bernier; Blackman Bay is included as a large tidal arm and a weak marginal zone.

Most of this coast consists of steep rocky cliffs and semi-exposed and exposed beaches are mainly restricted to areas within the major rocky bays (e.g. Wedge, Fortescue and Lagoon Bays and Port Arthur) and along a few exposed coastal sections (e.g. Pirates, North and Marion Bays). Sheltered beaches are found in the inner areas of Port Arthur, and Parsons and Blackman Bays and these have extensive stands of seagrasses.

Estuaries are restricted to a number of small tidal rivers amd those on exposed coasts are usually dammed.

(11) East Coast

This region extends from Cape Bernier north to Cape Tourville and includes Maria Island, Great Oyster Bay and the Great Swanport Estuary.

Most beaches along the mainland coast are partly protected by Freycinet Peninsula or Schouten and Maria Islands. Spring and Prosser Bays and Shoal Bay on Maria Island have large sheltered areas while beaches situated between rocky outcrops and headlands are semi-exposed. Nine Mile Beach, a bayhead spit at the northern end of Great Oyster Bay, is the longest continuous beach. This beach and associated dunes form a barrier across much of the Great Swanport, a large open lagoon.

Tidal rivers are notably absent from this region and other large estuarine systems are either open lagoons (e.g. Little Swanport and Earlham Lagoons) or bay estuaries (e.g. Maclaines Inlet). Closed systems, which are mostly polyhaline or euhaline, are generally bar-dammed (e.g. Kelvedon Lagoon). Few dune lakes are present in this region.

(12) Northern East Coast

This region extends from Cape Tourville to The Gardens and is characterised by a series of medium or long exposed beaches between prominent headlands.

Georges Bay, a large open lagoon, is dominated by marine conditions and *Heterozostera* and *Zostera* are the most common macrophytes. Euhaline conditions also predominate in a series of smaller bar-dammed lagoons although salinities vary seasonally.

(13) North-East Coast

This region extends from The Gardens to Petal Point, Cape Portland.

Sedimentary habitats of this coast occur mainly as semi-exposed or exposed beaches. Little Musselroe and Musselroe Lagoons and Ansons Bay are medium or large open lagoons with euhaline characteristics. Smaller systems are represented by a series of small coastal lakes and bar-dammed rivers.

Some small sheltered beaches with extensive seagrass beds are present in shallow reef protected areas around Cape Portland.

(14) Eastern North Coast

This region extends from Petal Point west to Five Mile Bluff. It consists of long expanses of semi-exposed beaches between rocky reefs, cliffs and promontories but beaches facing the north-west (e.g. Waterhouse and Boobyalla Beaches) are typically exposed. Sheltered beaches are absent from this region.

The largest estuarine systems, such as the Piper, Brid, Little Forester, Ringarooma and Tomahawk systems, are all tidal rivers. The coastal watershed of the eastern sector is reticulated with a number of drains. Small coastal lakes are abundant and Big Waterhouse Lake is the largest dune lake on the Tasmanian mainland.

(15) Tamar Estuary

This region includes the Tamar estuary and coastal region from Badgers Head in the west to Five Mile Bluff in the east.

The Tamar River is a large bay estuarine system receiving runoff from the Esk tributaries. A large tidal range facilitates entrainment and mixing of freshwater (Newell, 1969) resulting in a prevalence of marine conditions in the lower reaches. These conditions possibly enhance the establishment of marine seagrasses such as *Posidonia* which forms large stands in this estuary. Extensive areas of sand and mudflats are exposed at low tide in upstream areas.

Beaches outside the heads are semi-exposed.

(16) King Island

This region incorporates King Island and smaller islands nearby. The entire coast is exposed and a large proportion of the shore, particularly the west, is rocky. Although large exposed beaches are found in the north-east and north-west, Currie Harbour contains the only true sheltered beach habitat on King Island.

In contrast to the largest estuaries on the West Coast, the Ettrick and Yellow rock Rivers, which are tidal rivers, the Sea Elephant River on the East Coast is a typical open lagoon. Several smaller tidal rivers occur in the south and many are beach-dammed. Freshwater or oligohaline dune lakes are abundant in areas of the south and north.

4:4 STRUCTURE OF FISH COMMUNITIES

4:4:1 Faunal Assemblages of Major Habitats

Methods

Sample sites were assigned to one of 6 'major habitat types' based on the physical classification of environments presented in Section 4:3:3. These are as follows: (1) closed estuarine systems - basins separated from the sea at the time of sampling; (2) open estuarine systems (lower areas) - the lower half of estuarine and lagoon systems, including basins which normally remain closed but were open at the time of sampling; (3) open estuarine systems (upper areas) - the upper half of the above; (4) sheltered beaches; (5) semi-exposed beaches; and (6) exposed beaches.

Because preliminary studies indicated that the upper and lower regions of open estuarine systems may have rather different physical and biological attributes, they were separated for the purposed of this study. The total length of an estuary, defined as the distance from the mouth to the first riffle along the main channel, was first determined so that the halfway mark could be approximated. The mouths of most estuaries are clearly marked by an entrance channel but a few large bay estuaries, particularly those entering ria coasts, were difficult to delimit and their suggested seaward boundaries are illustrated in Appendix 4:3.

Occurrences of each species in each major habitat are given in Appendix 4:4. Standard residuals for the species with G-statistics greater than 15.09, the 0.01 level of significance with 5 degrees of freedom, are given in Appendix 4:5. These data were then analysed using Q- and R-mode analyses. Cluster analyses were used to examine faunal similarities between habitats.

Results and Discussion

Numbers of species

A total of 125 species was collected from 793 samples. Lower regions of open estuaries were sampled most intensively and produced the most species whereas sheltered beaches, which were less frequently sampled, yielded the highest number of species/sample (Table 4:1). Although there was a significant difference in the number of species occurring at each major habitat type (Table 4:2), the comparative density of species was difficult to assess as the sheltered beach sites also had the largest mean area sampled (Table 4:3).

A study of fishes in Californian bays and estuaries has shown that the relationship between the surface area of these systems (A) and the number of species occurring in them (S) is logarithmic (Horn and Allen, 1976). In the present study, data are in the form of total area swept for all samples taken in a major habitat type (see Table 4:3) rather than the combined surface areas of the systems representing a particular major habitat type. Nevertheless, a species number/area relationship described by the power function $S = 17.54A^{0.82}$, which had a correlation coefficient of 0.96 ($P < 0.01$), was calculated from these data. This rather high significance level suggests that habitat types, when sampled with equal sampling effort, would produce approximately equal numbers of species. Because catch compositions are less variable and contain small transient components in closed estuary and exposed beach samples, it is postulated that the faunas occurring in these major habitat types are smaller in size than those of the other major habitat types. Further sampling from closed estuaries and exposed beaches is required to test this hypothesis.

Significant seasonal effects were also evident, with numbers of species generally highest in summer and autumn and lowest in winter (Table 4:2).

Table 4:1. Number and densities of species at major habitats for each season. S - number of species, $\bar{S}$ - mean number of species per sample, N - no. of samples.

Major Habitats		Spring	Summer	Autumn	Winter	Total
		Seasons				
Closed systems	S	18	16	14	14	24
	$\bar{S}$	2.7	2.5	3.4	2.1	2.6
	N	15	21	9	16	61
Open systems (lower)	S	48	63	63	42	90
	$\bar{S}$	5.2	6.2	6.2	4.1	5.4
	N	78	69	73	85	305
Open systems (upper)	S	41	49	41	42	68
	$\bar{S}$	5.8	8.5	6.4	5.8	6.6
	N	35	26	31	28	120
Sheltered beaches	S	57	55	50	55	87
	$\bar{S}$	8.6	8.8	8.9	6.8	8.3
	N	40	28	36	41	145
Semi-exposed beaches	S	20	38	38	28	59
	$\bar{S}$	3.0	4.7	5.1	3.3	4.0
	N	29	36	30	36	131
Exposed beaches	S	6	9	7	4	10
	$\bar{S}$	1.8	2.3	4.5	1.7	2.6
	N	10	12	2	7	31

Table 4:2. Analysis of variance of species numbers by major habitat type and season.

	Degrees of freedom	Sum of Squares	Mean Square	F-ratio
Seasons	3	12.94	4.31	8.59**
Major habitats	5	103.47	20.69	41.23***
Error	15	7.53	0.50	

Table 4:3. Estimated area swept by the net at sampling sites at each major habitat. The inverse rate of appearance of extreme abundance classes, 1 (1,2 individuals), 4 (100-999 individuals) and 5 (greater than 1,000 individuals) for species is expressed as the observed frequency of occurrence of the abundance class at the appropriate major habitat.

	A (ha)	Estimated area swept by net $\bar{A}$ (m^2/sample)	Inverse rate of appearance of abundance classes in samples (samples/appearance)		
			Abundance Class		
			1	4	5
Closed systems	1.26	210	1.5	4.7	12.2
Open systems (lower)	9.94	330	0.6	3.5	33.9
Open systems (upper)	3.52	290	0.5	3.2	17.1
Sheltered beaches	7.53	520	0.4	1.9	14.5
Semi-exposed beaches	3.90	300	0.6	11.9	not occurring
Exposed beaches	0.69	220	1.1	15.5	not occurring

Q-mode analysis

Factor loadings of each major habitat type are given in Table 4:4. The first factor accounted for approximately 45% of the variance and provided a contrast between the faunas of estuarine and non-estuarine systems. Estuarine systems, particularly the upper and lower areas of open estuaries, were correlated positively while semi-exposed and exposed beaches exhibited high negative correlations. Hence, species that occupied the exposed beach environments generally tended to avoid estuaries and vice versa. 'Sheltered beaches' showed only a low negative correlation. This value, denoted by an overlap in species composition, suggests that sheltered beaches could have faunas that are transitory between estuarine and exposed beach habitats.

The second factor accounted for approximately 31% of the variance and provided a contrast between sheltered beaches and other habitats. A high negative correlation for sheltered beaches proved that some species preferred this habitat. The size of the positive factor may also give some indication of the faunal relationships between estuarine and exposed habitats. Highest positive loadings were obtained for 'closed estuaries' and 'exposed beaches' which were found from the first factor to be distinct from each other, and from this factor to be extremely dissimilar to 'sheltered beaches'. Consequently, based on its lowest positive loadings, the fauna of sheltered beaches is most similar to that of the lower areas of open estuaries.

The third factor exhibited a moderate negative correlation with the lower regions of open estuaries. Similarly, the fourth factor provided a moderate contrast between upper regions of open estuaries and closed estuarine systems. Although these factors only accounted for 21% of the variance they indicated that subtle faunal differences existed between the estuarine systems.

The fifth factor occupied only a small proportion of the variance and was unimportant.

Table 4:4. Factor loadings from Q-mode binary discriminant analysis of major habitat types.

Habitat type	Factor 1	2	3	4
Closed systems	.410	.645	.335	.551
Open systems (lower)	.788	.060	-.599	.107
Open systems (upper)	.705	.375	.309	-.516
Sheltered beaches	-.169	-.942	.246	.131
Semi-exposed beaches	-.899	.340	-.162	-.034
Exposed beaches	-.779	.552	-.016	-.059
Variance proportions	.455	.311	.109	.101

R-mode analysis

Factor loadings for each species on each of the rotated factors are given in Table 4:5.

The first rotated factor isolated 22 species and accounted for approximately 44% of the variance in the standardised residuals matrix. Factor scores indicated a contrast between 'sheltered beaches' and the faunas of other major habitats. High positive factor loadings indicated that these species had a preference for sheltered beaches and *Acanthaluteres spilomelanurus, Atherinason esox, Atherinason* sp., *Heteroclinus perspicillatus, Kathetosoma laeve, Neoodax balteatus, Neoodax semifasciatus* and *Nesogobius* sp. 7 had loadings exceeding 95%.

Understandably, most of these species were poorly correlated with the other factors; however, some species most highly correlated with factor 1 exhibited good correlations with one or more factors. For example, *Rhombosolea tapirina* and *Nesogobius* sp. 2 showed moderate positive correlations with factors 2 and 4. As indicated from the factor score matrix, 'lower estuaries' were highly positive for these factors. In other words, whilst these species exhibited a preference for sheltered beaches, they also occurred frequently in the mouths of open estuarine systems. Similarly, *Contusus* sp. was often

Table 4:5. Factor loadings, variance proportions, and factor scores for rotated factors based on major habitats.

Code No.	Species	Factor 1	2	3	4
1	*Neoodax balteatus*	.997	.054	-.029	.024
2	*Nesogobius sp.7*	.995	-.008	-.070	-.053
3	*Atherinason esox*	.992	-.072	-.092	-.045
4	*Neoodax semifasciatus*	.987	-.112	-.114	-.028
5	*Acanthaluteres spilomelanurus*	.979	.071	.130	.140
6	*Kathetostoma laeve*	.979	-.165	-.106	-.055
7	*Atherinason sp.*	.957	.043	-.226	.173
8	*Heteroclinus perspicillatus*	.951	.165	.182	.183
9	*Atherinosoma presbyteroides*	.946	-.081	.012	.297
10	*Leptonotus semistriatus*	.943	-.179	-.231	-.112
11	*Nesogobius hinsbyi*	.941	.085	-.180	.275
12	*Hippocampus breviceps*	.906	-.374	-.150	-.056
13	*Hyporhamphus melanochir*	.901	-.347	-.156	.210
14	*Stigmatopora argus*	.886	.099	.430	.142
15	*Penicipelta vittiger*	.878	.322	-.149	.305
16	*Meuschenia freycineti*	.849	.154	.490	.116
17	*Nesogobius sp.2*	.833	.405	.034	.374
18	*Cristiceps australis*	.805	.295	.452	.239
19	*Platycephalus bassensis*	.805	-.063	.426	.386
20	*Gymnapistes marmoratus*	.798	.285	.524	.070
21	*Contusus sp.*	.774	-.574	-.117	.033
22	*Rhombosolea tapirina*	.621	.552	.210	.511
23	*Tasmanogobius sp.3*	-.360	.904	-.200	.044
24	*Atherinosoma microstoma*	.056	.834	.488	-.211
25	*Pseudaphritis urvillii*	-.392	.822	.401	.068
26	*Galaxias truttaceus*	.564	.795	-.210	-.050
27	*Acanthopagrus butcheri*	-.498	.759	-.369	-.129
28	*Galaxias maculatus*	-.537	.680	.473	.149
29	*Pseudogobius olorum*	-.447	.615	.545	-.315
30	*Arripis trutta*	-.112	-.965	-.196	.102
31	*Syngnathus tuckeri*	.098	-.946	-.241	-.083
32	*Crapatalus sp.*	-.189	-.939	-.228	.008

Code No.	Species	Factor 1	2	3	4
33	*Ammotretis liturata*	-.256	-.927	-.232	-.104
34	*Taratretis derwentensis*	-.049	-.875	-.262	.064
35	*Crapatalus arenarius*	-.199	-.869	-.262	-.152
36	*Amoya bifrenatus*	-.020	.001	.985	-.172
37	*Girella tricuspidata*	-.038	-.085	.978	-.175
38	*Nesogobius sp.5*	.297	.249	.918	.076
39	*Favonigobius lateralis*	-.124	.307	.896	.295
40	*Syngnathus phillipi*	.493	.206	.843	.035
41	*Urocampus carinirostris*	-.223	.209	.834	-.440
42	*Favonigobius tamarensis*	-.231	.478	.832	.159
43	*Anguilla australis*	-.394	.436	.765	-.239
44	*Retropinna tasmanica*	-.408	.488	.713	.295
45	*Stigmatopora nigra*	.241	.531	.697	.408
46	*Torquigener glaber*	.293	.465	.607	.573
47	*Aldrichetta forsteri*	.213	-.258	.009	.940
48	*Ammotretis rostratus*	.444	.111	-.427	.750
Variance proportions		.443	.352	.130	.062

	Factor Scores			
Closed systems	-.355	.835	-.604	-1.581
Open systems (lower)	-.693	1.089	-.547	1.483
Open systems (upper)	-.244	.134	2.013	-.036
Sheltered beaches	2.017	.123	-.177	.224
Semi-exposed beaches	-.401	-1.684	-.432	.305
Exposed beaches	-.324	-.497	-.253	-.394

found on more exposed beaches and *Stigmatopora argus, Platycephalus bassensis, Gymnapistes marmoratus, Cyttus australis* and *Meuschenia freycineti* often ventured into upper areas of estuaries.

The second rotated factor, which accounted for 35% of the variance in the data matrix, contrasted 'exposed beaches' with 'closed' and 'lower estuarine' systems. Seven species exhibited positive correlations but apart from *Tasmanogobius* sp. 3 they also shared affinities with other major habitats. In comparison, those species with high negative loadings showed only low correlations with other factors. These, *Arripis trutta, Syngnathus tuckeri, Crapatalus arenarius, Crapatalus* sp., *Ammotretis liturata* and *Taratretis derwentensis,* occurred most frequently on semi-exposed and exposed beaches.

Rotated factor 3 provided a list of species which exhibited some preference for the upper part of estuaries. Apart from *Amoya frenatus, Girella tricuspidata, Nesogobius* sp. 5 and *Favonigobius lateralis,* species were only moderately correlated with other factors.

The fourth rotated factor comprised only 4% of the variance and from the factor score matrix contrasted 'open estuarine systems' with 'closed estuarine systems'. Two species, *Aldrichetta forsteri* and *Ammotretis rostratus,* had high positive loadings and appeared to most prefer habitats near the mouths of estuaries.

A plot of factor scores for species produced by the Q-mode B.D.A. demarcating species groups obtained from the R-mode analysis (Fig. 4:13) resulted in a good separation of major habitats. Exposed and semi-exposed beach species were segregated by high negative values for the first factor. The second factor discriminated between two major groups: the sheltered beach and a lower estuarine group which were concentrated in the north-west and an overlapping upper and closed estuary group concentrated in the north-east quadrant. As suggested earlier, there appeared to be some similarity between sheltered beach and lower estuary faunas.

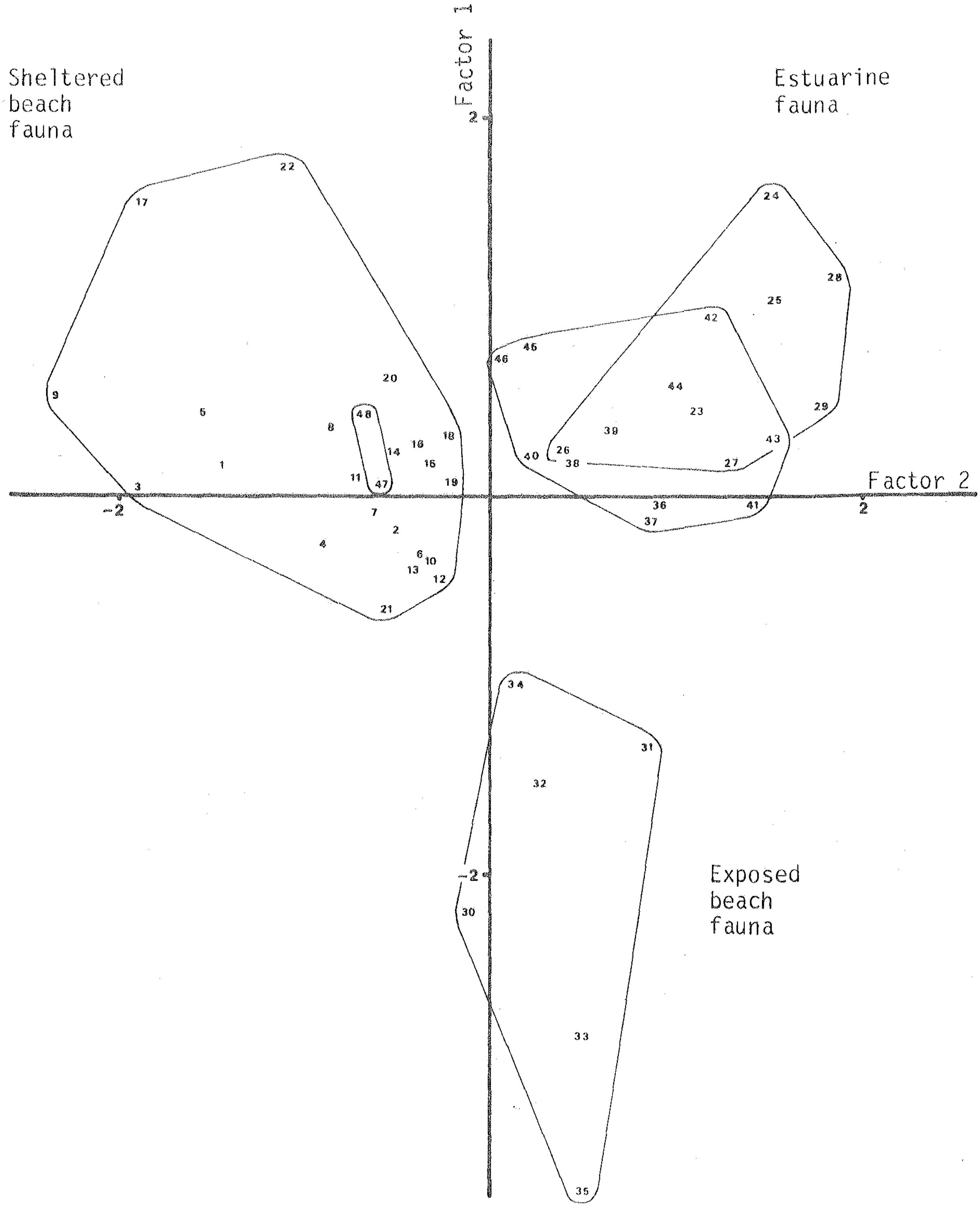


Fig. 4:13 . Fish species from major habitats plotted by factor scores on Factors 1 and 2 of Q-mode binary discriminant analysis. Species are coded and assembled according to Table 4:5.

Occurrences of species

Ranked percentage occurrences for the 10 most frequently occurring species at each major habitat are given in Table 4:6. Seven widespread species, *Aldrichetta forsteri*, *Ammotretis rostratus*, *Arripis trutta*, *Atherinosoma microstoma*, *Atherinosoma presbyteroides*, *Nesogobius* sp. 2 and *Rhombosolea tapirina*, dominated these lists and at least 5 were major species at each site. These species did, however, exhibit preferences for particular areas as illustrated in Figure 4:14. For example, *Arripis trutta* occurred most frequently on exposed beaches while *Atherinosoma microstoma* displayed a preference for closed systems and the upper areas of open systems. *Atherinosoma presbyteroides* and *Nesogobius* sp. 2 occurred frequently at sheltered beach habitats whereas *Ammotretis rostratus* was most dominant in lower open estuarine areas. *Aldrichetta forsteri* and *Rhombosolea tapirina* occurred frequently at several major habitats.

The presence at each major habitat of these widespread and frequently occurring species suggests that the habitats were essentially similar. Removal of the 7 widespread species from the faunal occurrence list, however, indicated that this appraisal was probably not justified (Table 4:7). The estuarine fauna was distinct from the sheltered beach fauna which in turn differed from the exposed beach fauna.

Abundances of species

The 5 principal species, or those that occurred most commonly as the most abundant species in a sample, from each major habitat are listed in Table 4:8. These species at each major habitat, with the exception of those occurring in the loser regions of open estuaries, were identical with the most frequently occurring species at each major habitat (see Table 4:6).

Fig. 4:14. Occurrence of widespread species at each major habitat. Percentage frequencies were based on a proportion of the number of times a species occurred at a habitat to the number of occurrences of the most common species at that habitat.

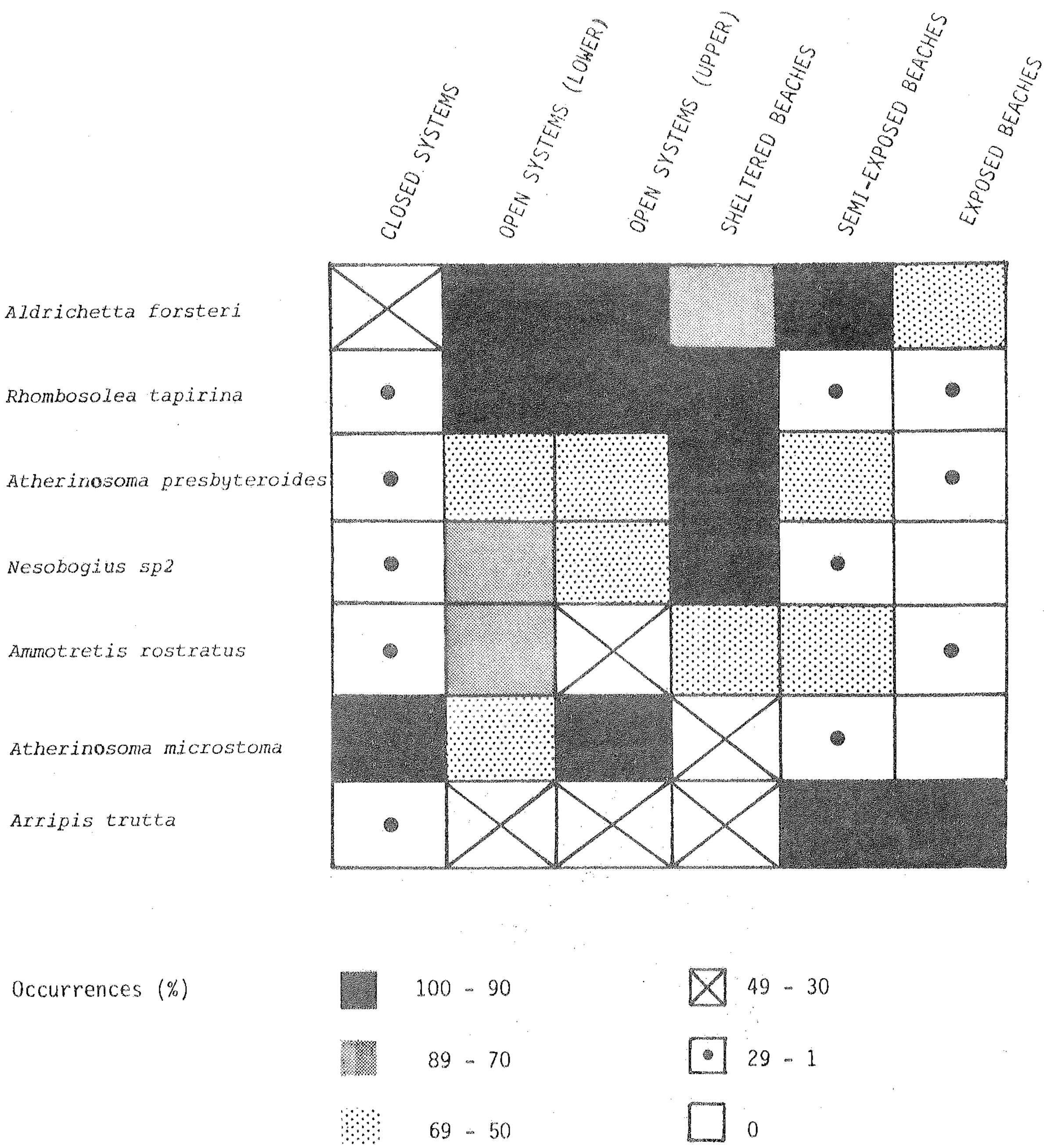


Table 4:6. Ranking by occurrence of the most common species from each major habitat type. Abundances of species were classed as follows: (1) 1, 2; (2) 3 - 9; (3) 10-99; (4) 100 - 999 and; (5) greater than 1000 individuals in a sample.

		Abundances					Occurrence (%)
		1	2	3	4	5	
Closed Systems							
1	*Atherinosoma microstoma*	2	4	15	10	4	57.4
2	*Aldrichetta forsteri*	2	7	2	1	1	21.3
	Pseudaphritis urvillii	5	3	4	1	0	21.3
4	*Galaxias maculatus*	3	5	4	0	0	19.7
5	*Pseudogobius olorum*	1	5	4	0	0	16.4
	Ammotretis rostratus	4	4	2	0	0	16.4
	Rhombosolea tapirina	6	2	2	0	0	16.4
8	*Tasmanogobius sp.3*	3	2	2	0	0	11.5
9	*Arripis trutta*	0	3	3	0	0	9.8
	Nesogobius sp.2	1	3	2	0	0	9.8
Open Systems(lower)							
1	*Aldrichetta forsteri*	30	71	64	12	1	58.4
2	*Rhombosolea tapirina*	46	65	50	3	0	53.8
3	*Ammotretis rostratus*	58	49	18	1	0	41.3
4	*Nesogobius sp.2*	21	54	47	2	0	40.7
5	*Atherinosoma microstoma*	16	23	41	28	3	36.4
6	*Atherinosoma presbyteroides*	6	9	56	24	4	32.5
7	*Arripis trutta*	16	33	26	2	1	25.6
8	*Galaxias maculatus*	24	25	17	4	0	23.0
9	*Pseudaphritis urvillii*	29	12	18	1	0	19.7
10	*Torquigener glaber*	19	23	6	0	0	15.7

Table 4:6 (cont.)

		Abundances					Occurrence (%)
		1	2	3	4	5	
Open Systems (upper)							
1	*Atherinosoma microstoma*	6	12	34	10	5	55.8
2	*Aldrichetta forsteri*	5	26	25	4	0	50.0
	Rhombosolea tapirina	20	20	19	1	0	50.0
4	*Favonigobius tamarensis*	10	18	12	0	0	33.3
5	*Atherinosoma presbyteroides*	0	12	14	9	2	30.8
6	*Galaxias maculatus*	6	16	12	3	0	30.8
	Nesogobius sp.2	8	20	8	1	0	30.8
8	*Pseudaphritis urvillii*	13	11	4	1	0	24.2
9	*Arripis trutta*	5	14	9	0	0	23.3
10	*Gymnapistes marmoratus*	13	8	4	1	0	21.7
Sheltered Beaches							
1	*Atherinosoma presbyteroides*	8	14	52	35	6	79.3
2	*Nesogobius sp.2*	10	27	62	11	0	75.9
3	*Rhombosolea tapirina*	18	44	41	0	0	71.0
4	*Aldrichetta forsteri*	12	35	29	8	0	57.9
5	*Ammotretis rostratus*	18	31	17	0	0	45.5
6	*Acanthaluteres spilomelanurus*	12	15	29	4	0	41.4
7	*Atherinosoma microstoma*	4	27	12	5	2	34.5
8	*Neoodax balteatus*	13	8	19	2	0	29.0
9	*Arripis trutta*	11	18	11	1	0	28.3
10	*Gymnapistes marmoratus*	19	16	5	0	0	27.6
Semi-exposed Beaches							
1	*Arripis trutta*	16	29	35	4	0	64.1
2	*Aldrichetta forsteri*	20	26	30	2	0	59.5
3	*Ammotretis rostratus*	23	20	3	0	0	35.1
4	*Atherinosoma presbyteroides*	1	13	26	4	0	33.6
5	*Crapatalus arenarius*	25	10	2	0	0	28.2
6	*Ammotretis liturata*	19	11	2	0	0	24.4
7	*Rhombosolea tapirina*	14	4	4	0	0	16.8
8	*Crapatalus sp.*	13	3	1	0	0	13.0
9	*Nesogobius sp.2*	2	7	5	0	0	10.7
10	*Contusus sp.*	3	5	2	0	0	7.6

Table 4:6 (cont).

Exposed Beaches		Abundances 1	2	3	4	5	Occurrence (%)
1	*Arripis trutta*	3	7	7	2	0	61.3
2	*Crapatalus arenarius*	8	6	2	0	0	51.6
3	*Aldrichetta forsteri*	6	4	2	0	0	38.7
4	*Ammotretis liturata*	5	4	0	0	0	29.0
5	*Ammotretis rostratus*	2	0	1	0	0	9.7
	Rhombosolea tapirina	3	0	0	0	0	9.7
7	*Crapatalus sp.*	0	2	0	0	0	6.5
8	*Hyporhamphus melanochir*	0	0	1	0	0	3.2
	Atherinosoma presbyteroides	0	1	0	0	0	3.2
	Syngnathus tuckeri	1	0	0	0	0	3.2

Arripis trutta was numerically dominant on semi-exposed and exposed beaches. The atherinid, *Atherinosoma microstoma,* was the principal species in closed systems and upper areas of open systems, and the congeneric, *Atherinosoma presbyteroides,* was clearly most numerous on sheltered beaches but was only marginally dominant in lower areas of open estuaries.

Twenty-two (72%) of the principal species from Table 4:8 compared with only 15 (50%) from the occurrence data (see Table 4:6), including only the 5 highest ranking species, were schooling species. Densities of schooling species were generally higher than for non-schooling species but, as distributions of the former were generally clumped, they possibly occurred less regularly in samples.

The distribution of abundance classes for major habitats (Fig. 4:15) indicated that mean abundances of species were highest in closed estuaries and lowest in exposed beach habiats. Abundance data of this type is

Table 4:7. Ranking by occurrence of most common species from each major habitat type after the widespread species (*Aldrichetta forsteri, Ammotretis rostratus, Arripis trutta, Atherinosoma microstoma, Atherinosoma presbyteroides, Nesogobius sp. 2* and *Rhombosolea tapirina*) had been omitted.

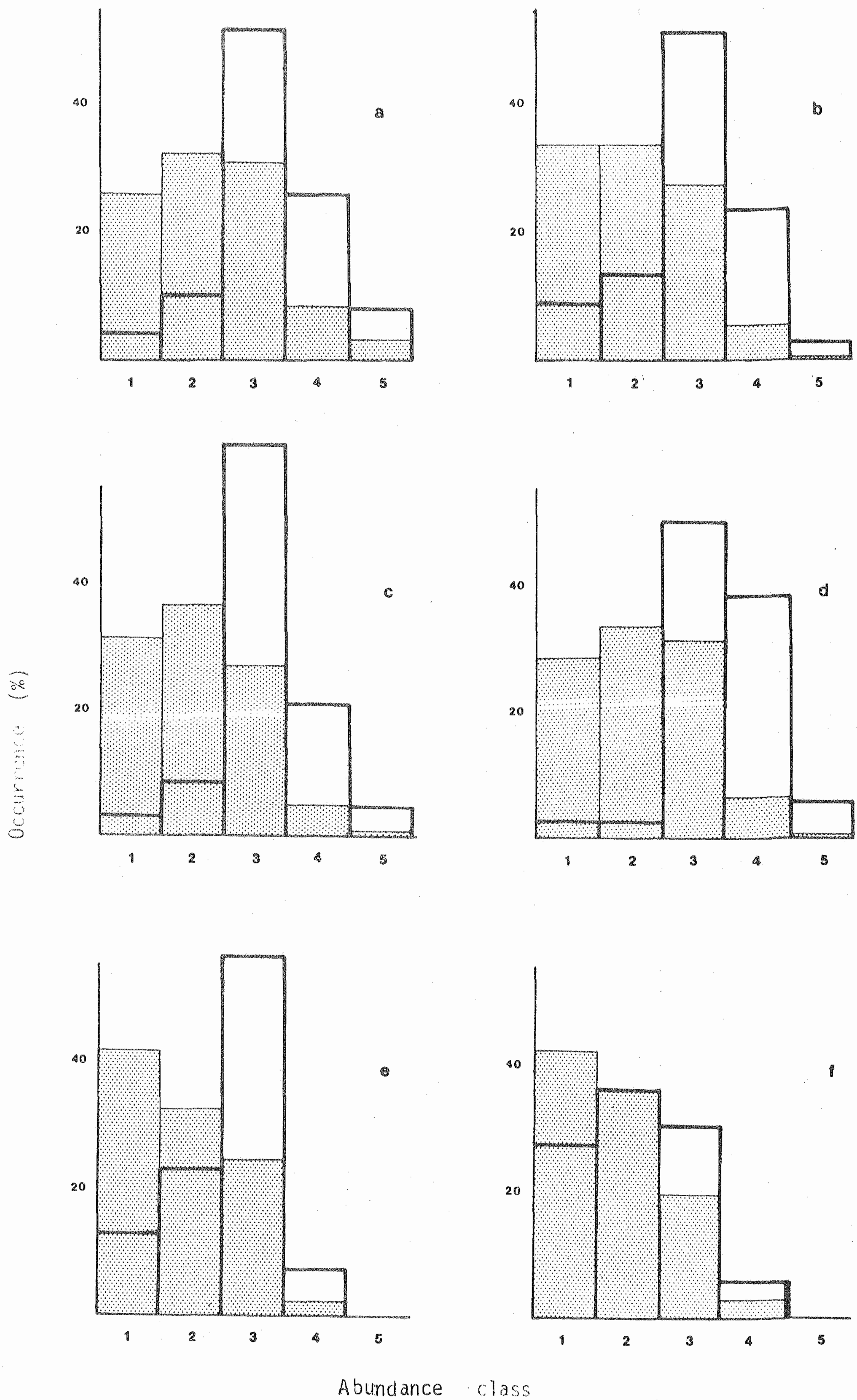
Rank	Closed systems	Open systems (lower)	Open systems (upper)
1	*Pseudaphritis urvillii*	*Galaxias maculatus*	*Favonigobius tamarensis*
2	*Galaxias maculatus*	*Pseudaphritis urvillii*	*Galaxias maculatus*
3	*Pseudogobius olorum*	*Torquigener glaber*	*Pseudaphritis urvillii*
4	*Tasmanogobius sp. 3*	*Favonigobius tamarensis*	*Gymnapistes marmoratus*
5	*Acanthopagrus butcheri*	*Stigmatopora nigra*	*Torquigener glaber*
6	*Anguilla australis*	*Acanthaluteres spilomelanurus*	*Stigmatopora nigra*
7	*Favonigobius tamarensis*	*Gymnapistes marmoratus*	*Pseudogobius olorum*
8	*Galaxias truttaceus*	*Tasmanogobius sp. 3*	*Acanthaluteres spilomelanurus*
9	*Urocampus carinirostris*	*Retropinna tasmanica*	*Retropinna tasmanica*
10	*Gymnapistes marmoratus*	*Pseudogobius olorum*	*Anguilla australis*

Rank	Sheltered beaches	Semi-exposed beaches	Exposed beaches
1	*Acanthaluteres spilomelanurus*	*Crapatalus arenarius*	*Crapatalus arenarius*
2	*Neoodax balteatus*	*Ammotretis liturata*	*Ammotretis liturata*
3	*Gymnapistes marmoratus*	*Crapatalus sp.*	*Crapatalus sp.*
4	*Atherinason esox*	*Contusus sp.*	*Hyporhamphus melanochir*
5	*Heteroclinus perspicillatus*	*Taratretis derwentensis*	*Syngnathus tuckeri*
6	*Stigmatopora argus*	*Syngnathus tuckeri*	-
7	*Torquigener glaber*	*Contusus richei*	-
8	*Meuschenia freycineti*	*Hyporhamphus melanochir*	-
9	*Nesogobius hinsbyi*	*Platycephalus bassensis*	-
10	*Platycephalus bassensis*	*Acanthaluteres spilomelanurus*	-

Table 4:8. Ranking of principal species from samples from each major habitat type where p is the proportion of samples in which the species was most abundant.

Habitat	Rank	Species	p (%)
Closed Systems	1	*Atherinosoma microstoma*	48.0
	2	*Pseudaphritis urvillii*	12.0
	3	*Galaxias maculatus*	8.0
	4	*Acanthopagrus butcheri*	6.0
	5	*Aldrichetta forsteri*	4.0
Open Systems (lower)	1	*Atherinosoma presbyteroides*	18.4
	2	*Atherinosoma microstoma*	17.8
		Aldrichetta forsteri	17.8
	4	*Rhombosolea tapirina*	9.2
	5	*Arripis trutta*	5.9
Open Systems (upper)	1	*Atherinosoma microstoma*	27.7
	2	*Galaxias maculatus*	13.4
	3	*Atherinosoma presbyteroides*	12.6
	4	*Aldrichetta forsteri*	11.8
	5	*Stigmatopora nigra*	5.0
Sheltered Beaches	1	*Atherinosoma presbyteroides*	41.8
	2	*Nesogobius sp. 2*	15.1
	3	*Aldrichetta forsteri*	9.6
	4	*Atherinosoma microstoma*	5.5
	5	*Acanthaluteres spilomelanurus*	4.1
Semi-exposed Beaches	1	*Arripis trutta*	37.4
	2	*Aldrichetta forsteri*	19.1
	3	*Atherinosoma presbyteroides*	16.8
	4	*Ammotretis rostratus*	6.1
	5	*Nesogobius sp. 2*	3.1
Exposed Beaches	1	*Arripis trutta*	36.4
	2	*Crapatalus arenarius*	24.2
		Ammotretis liturata	24.2
	4	*Aldrichetta forsteri*	3.0
		Hyporhamphus melanochir	3.0

Fig. 4:15. Relative occurrence of abundance classes at each major habitat based on data including all species (shaded columns) and only the principal species (heavily outlined columns) from each sample. Major habitats and abundance classes are represented by the following: (a) closed estuaries, (b) open estuaries (lower), (c) open estuaries (upper), (d) sheltered beaches, (e) semi-exposed beaches and (f) exposed beaches; (1) 1-2, (2) 3-9, (3) 10-99, (4) 100-999, and (5) greater than 1,000 individuals.


Occurrence (%)
40
20
a
b
c
d
e
f
1
2
3
4
5
Abundance class

comparative only if the sampling strategies are similar. Possible biases in this study, as mentioned previously, could have been introduced by differences in the mean area sampled at each habitat (see Table 4:3).

The most obscure trends were probably evident in the normal abundance class distributions of species living on sheltered beaches. The numbers of individuals caught from these habitats,reflected by the abundance distribution of principal species (Fig. 4:15), was often high. However, although several species were abundant within each sample (i.e. inverse rate of appearance of abundance classes 4 and 5 were 1.9 and 14.5 samples/ appearance respectively; see Table 4:3), their effect on the structure of abundance classes was depressed by the relatively high co-occurrence of several incidental species (i.e. inverse rate of appearance of abundance class 1 was 0.4 samples/appearance).

In comparison, closed estuarine systems, which appear to have a smaller fauna than sheltered beaches, exhibited a distribution of principal species favouring the higher abundance classes. A relatively low number of incidental species and a high number of abundant species was reflected by the high and low inverse rates of appearance of abundance classes 1 and 5 respectively (see Table 4:3).

Similarity of habitats

Centroid analysis provided some supportive evidence of relationships between major habitat types (Fig. 4:16). The faunas of sheltered beaches and the lower regions of open estuaries were identified as most similar.

'Open estuaries' were least similar to 'exposed beaches' but both were removed from the other habitats. Lower numbers of species sampled in these habitats compared to other habitat types could explain their uniformly lower similarity values (Appendix 4:6).

These analyses, repeated after the removal of the 7 widespread species *Aldrichetta forsteri*, *Ammotretis rostratus*, *Arripis trutta*, *Atherinosoma*

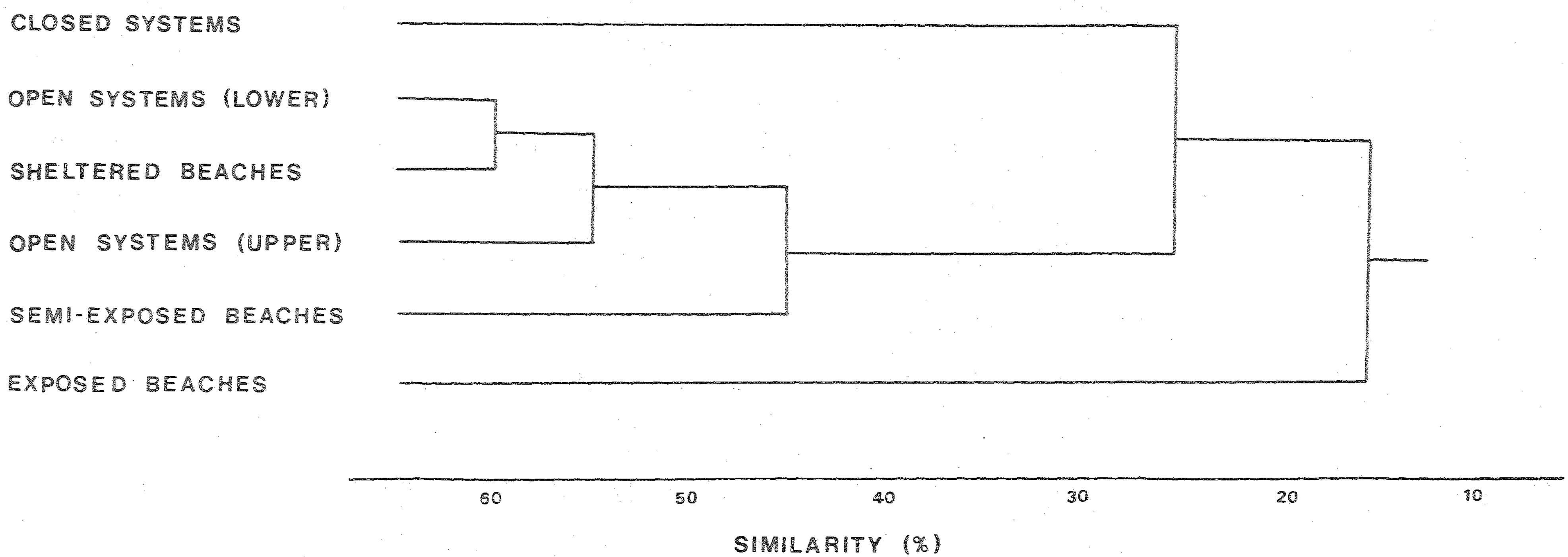


Fig. 4:16. Similarity in the compositions of fish species occurring at major habitat types determined from centroid cluster analysis.

microstoma, Atherinosoma presbyteroides, Nesogobius sp. 2 and *Rhombosolea tapirina,* resulted in an identical classification of groups but with reduced similarities between groups (Appendix 4:6). Closed estuaries were most similar to the upper areas of open estuarine systems. In contrast, exposed beaches exhibited zero similarity with the closed estuaries and most closely resembled semi-exposed and sheltered beaches.

Faunas of semi-exposed beaches were most similar to sheltered beaches. This relationship, not evident from earlier analyses, may have been related to the occurrence of seagreasses in some semi-exposed areas. A few seagrass preferring species, normally inhabiting sheltered habitats, occur in semi-exposed habitats when seagrasses are present. They have low occurrences, low rank and non-significant G-statistics but can influence analyses based on single binary data.

Comments

Although the 6 major habitat types did not comprise 6 well-defined biotopes, the B.D.A. analysis suggested that some community characteristics were evident with some species clearly showing preferences for particular habitat types. Rankings of the most frequently occurring species in each habitat demonstrated a faunal association based on the presence of several species ubiquitous to inshore sedimentary environments. A comparison of species composition between habitats, after removal of these species, exposed more subtle faunal trends.

Biotopes have been generally characterised by their indicator species (Hesse *et al.,* 1937). Some species identified by R-mode analysis could be classed as indicators but the true relationships are undoubtedly more complex. Some widespread species were occurrence and abundance dominants at particular habitat types and as such, could be regarded as indicators. However, if an 'indicator' is to be truly representative of a biotope then it should exhibit a high degree of fidelity for that biotope. In this study, some less frequently occurring species appeared to have more specific preferences for these habitats. Unlike their widespread co-inhabitants, most were less mobile, higher fidelity, non-migratory species and could be better indicators of the faunal relationships between habitats.

In conclusion, analyses and data summaries indicate that at least 3 broad fish assemblages exist; an estuarine fauna inhabiting both open and closed systems; a sheltered beach fauna; and a fauna that inhabits exposed and semi-exposed beaches. The following sections examine community structure within each of these assemblages.

4:4:2 Faunal Assemblages of Estuarine Habitats

Methods

The 3 major habitats of estuarine systems (see Section 4:4:1) were subdivided into 40 minor habitat types. These represented whole systems or, in some cases, parts of systems possessing recognisable differences in their physical characteristics (see Section 4:3:3).

Minor habitats of estuaries are summarised by the following:

1. Coastal Lakes
2. Bar-dammed Lagoons - area nearest sea (seaward 50 m of basin).
3. " " " - areas other than those in 2.
4. " " " - connection to the sea at the time of sampling.
5. Bar-dammed Rivers - area nearest the sea (seaward 50 m of basin).
6. " " " - with a connection to the sea at the time of sampling.
7. Beach-dammed Rivers - area nearest the sea (seaward 50 m of basin).
8. " " " - areas other than those in 7.
9. " " " - with a connection to the sea at the time of sampling

10. Open Lagoons, barway.

11. " " , mouth.

12. " " , mid-lower

13. " " , mid.

14. " " , mid-upper

15. " " , pre-riffle.

16. Bay Estuaries (deep), mouth

17. " " " , mid-lower.

18. " " " , mid.

19. " " " , mid-upper.

20. " " " , pre-riffle.

21. Bay Estuaries (flats), mouth.

22. " " " , mid-lower.

23. " " " , mid.

24. " " " , mid-upper.

25. " " " , pre-riffle.

26. Tidal Rivers, bar.

27. " " , mouth.

28. " " , mid-lower.

29. " " , mid.

30. " " , mid-upper.

31. " " , pre-riffle.

32. " " , post-riffle.

33. Tidal Creeks, bar.

34. " " , mouth.

35. " " , mid-lower.

36. " " , mid.

37. " " , pre-riffle.

38. " " , post-riffle.

39. Tidal Tributaries, lower areas.

40. " " , upper areas.

The length of an estuary has been defined in Section 4:4:1. 'Mouth', 'mid-lower', 'mid', 'mid-upper' and 'pre-riffle' represented 5 continuous and equal divisions of open estuaries whereby 'mouth' and 'pre-riffle' denoted the extreme lower and upper regions respectively. The post-riffle region was situated in freshwater above the first riffle while the bar region represented a marginal area in the sea outside the estuary mouth.

Bay estuarine sites were subdivided into deep areas (involving the main channels) and flat areas (over shallow tidal flats).

Minor habitats can be categorised into the following major habitat types. closed systems 1 - 3, 5, 7 and 8; lower areas of open systems 4, 6, 9 - 12, 16, 17, 21, 22, 26 - 28, 33 - 35 and 39; and upper areas of open systems 13 - 15, 18 - 20, 23 - 25, 29 - 32, 36 - 38 and 40.

Twenty-five species showed responses to minor habitat types which were significant to the 0.1 level (degrees of freedom = 39, G-statistic cutoff = 50.66) (Appendix 4:7). These data were analysed using Q- and R-mode analyses.

Results and discussion

Numbers of species

Total numbers of species and the mean numbers of species per sample for each type of minor habitat (ignoring the effects of position in the estuary) are given in Table 4:9.

Differences in faunal complexity were difficult to assess owing to variable numbers of samples taken at each minor habitat type. Nevertheless, some trends were evident.

Table 4:9. Numbers of species collected at minor habitats of estuaries.

	Number of samples	Number of species	Mean number of species per sample
Coastal lakes	16	4	0.5
Bar-dammed lagoons	26	23	3.2
Bar-dammed rivers	6	11	4.5
Beach-dammed rivers	13	12	2.0
Open lagoons	115	77	8.3
Bay estuaries (deep)	95	61	5.2
Bay estuaries (flats)	36	49	6.2
Tidal rivers	70	30	4.2
Tidal creeks	45	34	3.2
Tidal tributaries	20	24	3.4

Coastal lakes were rather depauperate of species. In comparison, open lagoons, the most heavily sampled minor habitat, had a rich fauna and had by far the highest average number of species per sample. Bay estuarine systems possessed a more complex fish fauna than tidal rivers and the fish faunas of bar-dammed rivers appeared to be richer than the beach-dammed rivers of the West Coast. Mean numbers of species in samples from most dammed systems were similar to those values obtained from tidal creeks, rivers and tributaries.

Q-mode analysis

The variance of the standard residuals matrix was dispersed over 24 factors which indicated that the minor habitat types were not highly correlated. Consequently, only the first 4 factors which occupied approximately 57% of the variance are given in Table 4:10.

The relationship of the minor habitats with the first factor was difficult to interpret. Negatively correlated ' areas of open lagoons' (habitats 11, 12, 13, 15) and 'mouths of bay estuarine systems' (habitat 16) were contrasted with several minor habitats. Of these, 'coastal lakes' (habitat 1), 'closed basins connected to the sea' (habitats 4, 9), 'areas of tidal rivers' (habitats 29, 32) and most areas of 'tidal creeks and tributaries' had the highest positive factor loadings. 'Mid-upper regions of open lagoons' (habitat 14), however, exhibited a moderate positive correlation with this factor.

Correlations within the second factor were even more difficult to elucidate, and accounted for only 12.4% of the variance in the residuals matrix. The most highly correlated variable, 'mid-lower areas of estuarine flats', had a factor loading of less than 0.7. The third and fourth factors were equally difficult to interpret.

R-mode analysis

The first rotated factor accounted for approximately 37% of the variance (Table 4:11). Minor habitats with high positive scores on this factor include 'areas of open lagoons' (habitats 11, 12, 14), 'pre-riffle estuarine flats' (habitat 25) and 'bars of tidal rivers' (habitat 26) (Figs. 4:18, 19).

Highest negative scores were obtained for upper areas of 'deep bay estuaries' (habitats 18 - 20) and 'bar-dammed systems' (habitats 2 - 6).

Table 4:10. Factor loadings from Q-mode binary discriminant analysis of estuarine habitat type.

Code	Habitat type	Factor 1	2	3	4
1	Coastal lakes	.613	-.577	-.096	-.334
2	Bar-dammed lagoons (lower)	.301	.297	-.740	.002
3	Bar-dammed lagoons (middle and upper)	.081	.685	-.156	.193
4	Bar-dammed lagoons (open)	.860	.004	-.134	-.086
5	Bar-dammed rivers (lower)	.480	.029	-.579	.135
6	Bar-dammed rivers (open)	.752	-.167	.198	.015
7	Beach-dammed rivers (lower)	-.150	.501	-.632	-.071
8	Beach-dammed rivers (middle and upper)	-.372	.656	-.063	-.373
9	Beach-dammed rivers (open)	.785	-.007	.248	.001
10	Open lagoons (bar)	-.360	-.068	.325	.135
11	Open lagoons (mouth)	-.704	-.235	.338	.121
12	Open lagoons (mid-lower)	-.766	-.367	.166	.145
13	Open lagoons (mid)	-.643	.126	.361	.040
14	Open lagoons (mid-upper)	.650	.298	.127	.232
15	Open lagoons (pre-riffle)	-.747	-.226	.263	.074
16	Bay estuaries, deep (mouth)	-.730	-.131	.110	.012
17	Bay estuaries, deep (mid-lower)	-.081	.069	-.206	-.499
18	Bay estuaries, deep (mid)	-.235	.530	.260	-.113
19	Bay estuaries, deep (mid-upper)	.294	.430	.320	.400
20	Bay estuaries, deep (pre-riffle)	-.128	.674	-.171	-.201
21	Bay estuaries, flats (mouth)	.458	-.117	.214	-.201
22	Bay estuaries, flats (mid-lower)	.502	.694	.115	.257
23	Bay estuaries, flats (mid)	.522	-.156	.071	-.201
24	Bay estuaries, flats (mid-upper)	-.319	-.330	-.077	-.351
25	Bay estuaries, flats (pre-riffle)	-.236	-.479	-.544	.187
26	Tidal rivers (bar)	-.154	-.471	-.562	.181
27	Tidal rivers (mouth)	.456	.133	.460	.067
28	Tidal rivers (mid-lower)	.189	.101	.039	-.432
29	Tidal rivers (mid)	.762	.076	.119	-.109
30	Tidal rivers (mid-upper)	-.060	.117	.211	-.461

Table 4:10 (cont.).

Code	Habitat type	Factor 1	2	3	4
31	Tidal rivers (pre-riffle)	-.244	.105	.274	-.625
32	Tidal rivers (post-riffle)	.834	-.149	-.120	-.088
33	Tidal creeks (bar)	-.012	.615	.130	-.423
34	Tidal creeks (mouth)	.445	.237	-.002	.311
35	Tidal creeks (mid-lower)	.636	-.236	.288	.221
36	Tidal creeks (mid)	.413	-.607	-.052	-.389
37	Tidal creeks (pre-riffle)	.778	-.082	.150	.164
38	Tidal creeks (post-riffle)	.603	-.127	.526	.035
39	Tidal tributaries (lower)	.618	-.166	.205	-.226
40	Tidal tributaries (upper)	.822	-.069	-.268	-.082
	Variance proportions	.285	.124	.093	.065

Five marine species, *Meuschenia freycineti, Stigmatopora nigra, Acanthaluteres spilomelanurus, Heteroclinus perspicillatus* and *Stigmatopora argus,* exhibited high positive correlations with this factor and these fish were also found in association with non-estuarine seagrasses (see Section 4:5:2). The presence of well developed seagrass habitats, particularly in open lagoons, combined with the euryhalinity of these species (see Section 4:5:1), could explain their apparent preference for these habitats. Two other species, *Atherinosoma presbyteroides* and *Nesogobius* sp. 2, although most correlated with factor 1, also had moderately high factor loadings on factor 5.

Tasmanogobius sp. 3 exhibited only a low negative correlation with factor 1 which suggested that no species were strongly avoiding open lagoon habitats.

Table 4:11. Factor loadings, variance proportions, and factor scores for rotated factors based on estuarine habitats.

Code No.	Species	Factor 1	2	3	4	5
1	*Meuschenia freycineti*	.917	.164	.010	.225	.120
2	*Stigmatopora nigra*	.888	.098	.163	.162	.229
3	*Acanthaluteres spilomelanurus*	.876	.052	.093	.102	.312
4	*Heteroclinus perspicillatus*	.829	-.005	.073	.044	.367
5	*Stigmatopora argus*	.720	.110	.393	-.030	.102
6	*Atherinosoma presbyteroides*	.710	-.092	.081	-.124	.535
7	*Nesogobius sp.2*	.654	-.208	.163	.045	.542
8	*Tasmanogobius sp.3*	-.347	.309	-.231	-.285	.019
9	*Atherinosoma microstoma*	.074	.814	.315	.011	.004
10	*Pseudogobius olorum*	.032	.773	-.004	-.179	-.161
11	*Urocampus carinirostris*	.603	.616	-.040	.353	-.131
12	*Pseudaphritis urvillii*	-.049	.613	-.179	-.594	-.103
13	*Favonigobius tamarensis*	.356	.478	.443	-.092	.182
14	*Favonigobius lateralis*	.232	.125	.750	.308	.189
15	*Platycephalus bassensis*	.015	-.160	.723	-.009	.386
16	*Gymnapistes marmoratus*	.460	.248	.681	.051	.053
17	*Anguilla australis*	-.081	.218	.664	-.235	-.327
18	*Contusus richei*	.247	-.261	.417	-.065	.325
19	*Retropinna tasmanica*	-.092	.136	.049	-.885	.023
20	*Galaxias maculatus*	-.151	-.019	.020	-.760	-.424
21	*Rhombosolea tapirina*	.269	.001	.152	.019	.823
22	*Ammotretis rostratus*	.076	-.222	-.045	.163	.795
23	*Arripis trutta*	.129	.070	.035	.210	.780
24	*Aldrichetta forsteri*	.416	.019	.161	.121	.712
25	*Torquigener glaber*	.436	-.069	.248	-.052	.658
Variance proportions		.367	.147	.087	.074	.057

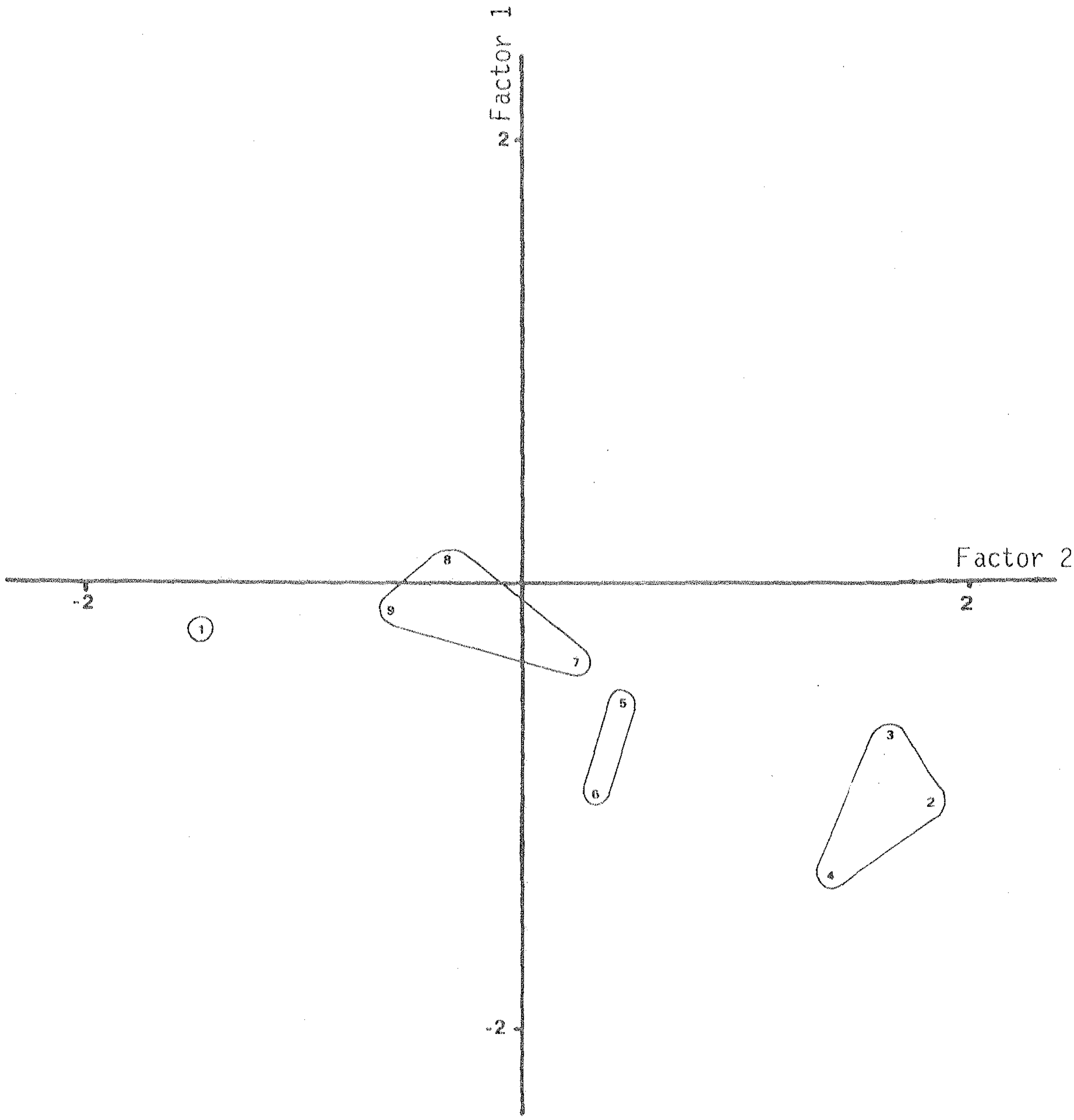


Fig. 4:17. . Closed estuaries plotted by factor scores on Factors 1 and 2 of R-mode discriminant analysis. Minor habitats are coded and estuarine types grouped according to Table 4:10.

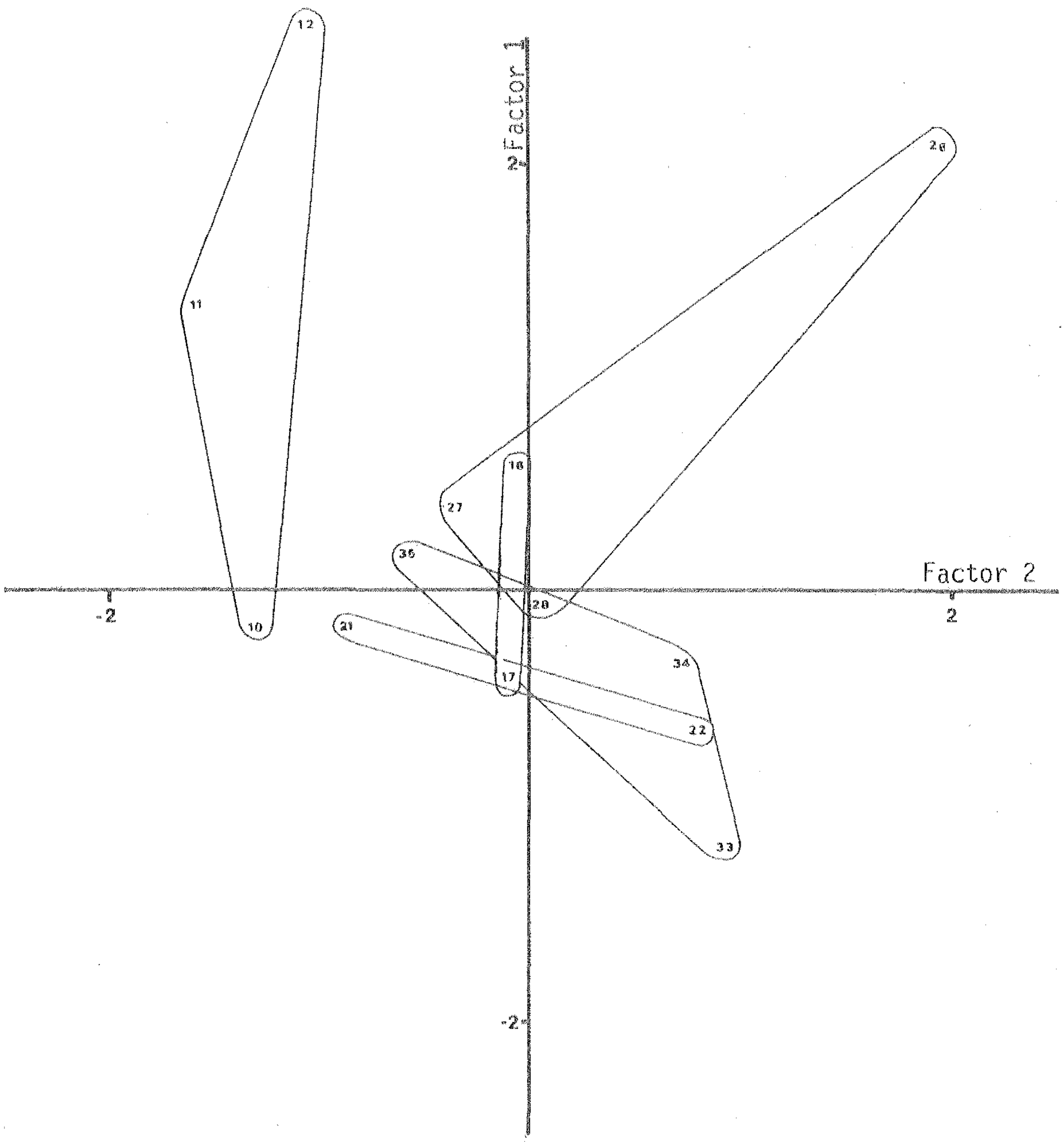


Fig. 4:18. Lower regions of open estuaries plotted by factor scores on Factors 1 and 2 of R-mode binary discriminant analysis. Minor habitats are coded and estuarine types grouped according to Table 4:10.

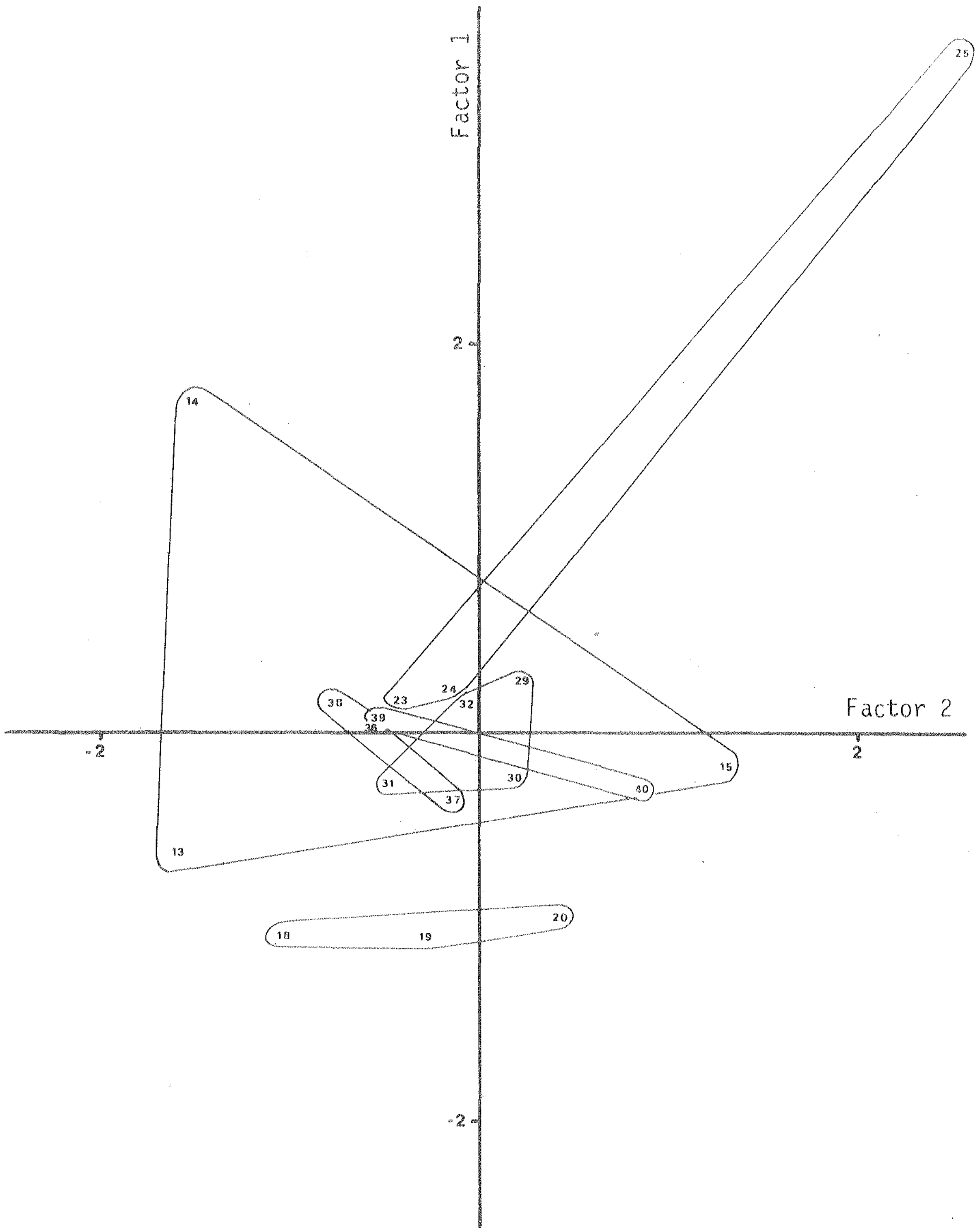


Fig. 4:19. Upper regions of open estuaries plotted by factor scores on Factors 1 and 2 of R-mode binary discriminant analysis. Minor habitats are coded and estuarine types grouped according to Table 4:10.

The second rotated factor united two widely separated habitat types. High positive factor scores were obtained for 'bar-dammed systems' (habitats 2 - 4) and the 'entrances of tidal creeks and rivers' (habitats 26, 33, 34) (Figs. 4:17, 18). Some 'pre-riffle areas' (habitats 15, 25) and 'upper tidal tributaries' (habitat 40), however, also had high positive factor scores. A general trend amongst the most variable upper estuary groups to have upstream habitats displaced to the right (more positive values on the x-axis) was evident.

The 5 species, *Atherinosoma microstoma, Pseudogobius olorum, Urocampus carinirostris, Pseudaphritis urvillii* and *Favonigobius tamarensis* that correlated most highly with factor 2 were among the most euryhaline (see Section 4:5:1) and can possibly be regarded as true estuarine species. In euhaline estuaries these species were most abundant upstream while in meso- or oligohaline systems they usually occurred downstream.

The third rotated factor accounted for approximately 9% of the variance. The 'mid-upper region of estuarine flats' had a high positive score (i.e. 5.27) while no other minor habitat scored greater than 1.0 (see Appendix 4:8). The species most highly correlated with this factor, *Favonigobius lateralis, Platycephalus bassensis, Gymnapistes marmoratus, Anguilla australis* and *Contusus richei,* must share some affinity with this minor habitat but the significance of this grouping is unclear.

Two species, *Retropinna tasmanica* and *Galaxias maculatus,* showed high negative correlations with the fourth rotated factor. High factor scores suggested that these species were most abundant in the middle areas of deep bay estuaries and in the middle and lower parts of tidal rivers.

The fifth rotated factor identified 5 widespread species, *Rhombosolea tapirina, Ammotretis rostratus, Arripis trutta, Aldrichetta forsteri* and *Torquigener glaber* (see Section 4:4:1).

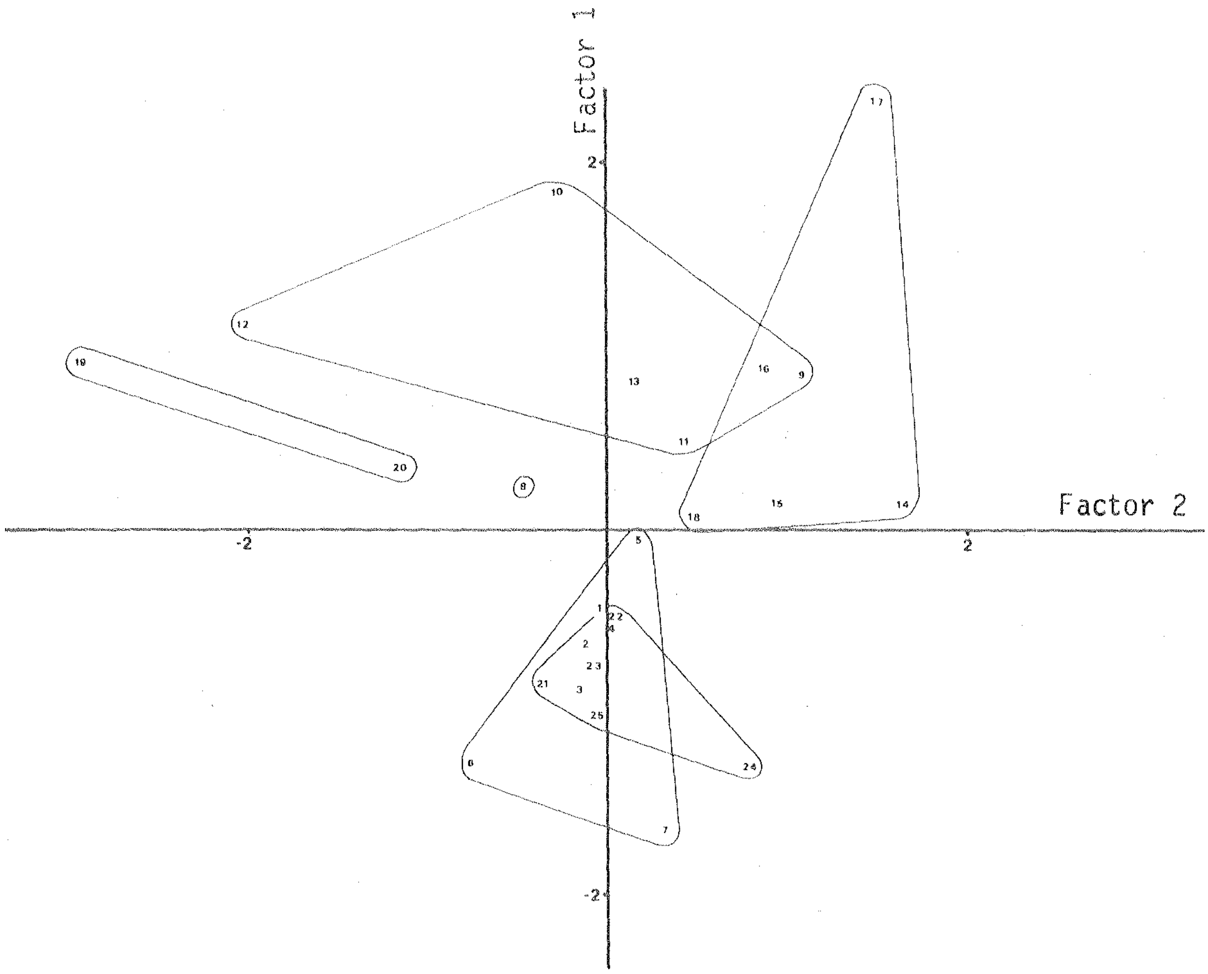


Fig. 4:20. . Fish species from estuarine habitats plotted by factor scores on Factors 1 and 2 of Q-mode binary discriminant analysis. Species are coded and assembled according to Table 4:11.

Scores for the 25 species were plotted on the first two factors constructed from the Q-mode analysis (Fig. 4:20). Group clusters determined from R-mode analysis supported evidence of faunal differences within estuaries. Those species in the upper quadrants preferred lower salinity, upper estuarine areas; those in the bottom quadrants preferred lower, more marine, areas of estuaries. The second factor provided a contrast between groups 4 and 5 from Table 4:11.

Occurrence and abundance of species

Ranked occurrences of species with their abundances are presented for each minor habitat (Table 4:12).

Closed systems exhibited some obvious faunal anomalies. *Atherinosoma microstoma* was the dominant species collected from coastal lakes but, although abundant in saltpans, it was rarely found in freshwater dune lakes. Freshwater species such as *Galaxias maculatus, Galaxias truttaceus* and *Nannoperca australis* were found in larger freshwater lakes, but many smaller basins were devoid of fish.

The faunas of bar-dammed rivers and lagoons were likewise dominated by the presence of *Atherinosoma microstoma.* Marine species, *Aldrichetta forsteri, Rhombosolea tapirina* and *Ammotretis rostratus*, were collected at seepage zones nearest the sea but were absent from other areas of these systems. These species probably migrated into the basin and became trapped on closure. Other marine species occurring less commonly in these areas were *Leptonotus semistriatus, Arripis trutta, Nesogobius* sp. 2, *Neoodax balteatus, Gymnapistes marmoratus, Myxus elongatus, Atherinosoma presbyteroides* and *Scorpaena ergastulorum.*

The fauna of bar-dammed lagoons and rivers, when open, were expanded by the immigration of widespread marine species, (e.g. *Rhombosolea tapirina, Ammotretis rostratus, Aldrichetta forsteri* and *Arripis trutta*). Other

Table 4:12. Ranking by occurrence of the most common species from each minor habitat from the estuaries. Abundances of species were classed as follows: (1) 1, 2; (2) 3 - 9; (3) 10 - 99; (4) 100 - 999 and; (5) greater than 1000 individuals in a sample.

		Abundances					Occurrence (%)
		1	2	3	4	5	
Coastal lakes							
1	*Atherinosoma microstoma*	0	0	0	3	0	18.8
Bar-dammed lagoons (lower)							
1	*Atherinosoma microstoma*	1	2	6	4	2	88.2
2	*Aldrichetta forsteri*	1	4	1	1	0	41.2
3	*Rhombosolea tapirina*	4	0	2	0	0	35.3
	Ammotretis rostratus	3	2	1	0	0	35.3
5	*Pseudogobius olorum*	0	1	3	0	0	23.5
Bar-dammed lagoons (middle and upper)							
1	*Atherinosoma microstoma*	1	0	5	2	1	100.00
2	*Tasmanogobius sp.3*	2	1	1	0	0	44.4
3	*Pseudaphritis urvillii*	3	0	0	0	0	33.3
Bar-dammed lagoons (open)							
1	*Atherinosoma microstoma*	1	1	5	5	0	70.6
2	*Rhombosolea tapirina*	5	2	1	1	0	52.9
3	*Ammotretis rostratus*	3	3	2	0	0	47.1
4	*Aldrichetta forsteri*	1	2	3	1	0	41.2
5	*Arripis trutta*	0	1	3	0	1	29.4

Table 4:12 (cont.).

		Abundances 1	2	3	4	5	Occurrence (%)
Bar-dammed rivers (lower)							
1	*Atherinosoma microstoma*	0	1	1	1	1	66.7
	Aldrichetta forsteri	1	1	1	0	1	66.7
3	*Pseudaphritis urvillii*	0	0	3	0	0	50.0
	Ammotretis rostratus	1	1	1	0	0	50.0
	Rhombosolea tapirina	2	1	0	0	0	50.0
Bar-dammed rivers (open)							
1	*Aldrichetta forsteri*	0	0	4	2	0	100.00
2	*Arripis trutta*	0	1	4	0	0	83.3
3	*Ammotretis rostratus*	2	0	2	0	0	66.7
Beached-dammed rivers (lower)							
1	*Galaxias maculatus*	0	3	2	0	0	45.5
2	*Atherinosoma microstoma*	0	1	3	0	0	36.4
	Pseudogobius olorum	1	2	1	0	0	36.4
4	*Pseudaphritis urvillii*	0	3	0	0	0	27.3
5	*Aldrichetta forsteri*	2	7	2	1	1	18.2
Beached-dammed rivers (middle and upper)							
1	*Galaxias truttaceus*	0	0	1	0	0	50.0
	Pseudaphritis urvillii	0	0	1	0	0	50.0
Beached-dammed rivers (open)							
1	*Galaxias maculatus*	1	1	2	0	0	66.7
2	*Anguilla australis*	1	0	1	0	0	33.3
	Pseudaphritis urvillii	1	0	1	0	0	33.3
4	*Galaxias truttaceus*	0	1	0	0	0	16.7
	Ammotretis rostratus	0	1	0	0	0	16.7
	Rhombosolea tapirina	0	1	0	0	0	16.7
	Tasmanogobius sp.3	0	1	0	0	0	16.7

Table 4:12 (cont.).

		Abundances					Occurrence (%)
		1	2	3	4	5	
Open lagoons (bar)							
1	*Atherinosoma presbyteroides*	0	0	0	0	1	100.00
	Nesogobius sp.2	0	0	1	0	0	100.00
	Platycephalus bassensis	0	1	0	0	0	100.00
	Crapatalus sp.	0	1	0	0	0	100.00
Open lagoons (mouth)							
1	*Atherinosoma presbyteroides*	0	0	8	3	0	73.3
	Aldrichetta forsteri	1	7	2	1	0	73.3
	Nesogobius sp.2	1	2	8	0	0	73.3
	Ammotretis rostratus	4	7	0	0	0	73.3
5	*Rhombosolea tapirina*	0	6	3	0	0	60.0
Open lagoons (mid-lower)							
1	*Aldrichetta forsteri*	5	18	14	1	0	82.6
2	*Nesogobius sp.2*	3	17	16	0	0	78.3
3	*Rhombosolea tapirina*	10	11	7	1	0	63.0
4	*Ammotretis rostratus*	12	9	4	0	0	54.3
5	*Atherinosoma presbyteroides*	2	1	18	3	0	52.2
Open lagoons (mid)							
1	*Atherinosoma microstoma*	0	3	8	3	1	68.2
	Aldrichetta forsteri	2	7	4	2	0	68.2
	Rhombosolea tapirina	4	8	3	0	0	68.2
4	*Nesogobius sp.2*	1	9	3	1	0	63.6
5	*Gymnapistes marmoratus*	4	5	1	1	0	50.0
Open lagoons (mid upper)							
1	*Aldrichetta forsteri*	1	12	6	2	0	87.5
2	*Atherinosoma microstoma*	1	3	10	1	3	75.0
3	*Rhombosolea tapirina*	5	6	4	1	0	66.7
4	*Atherinosoma presbyteroides*	0	4	6	2	0	50.0
5	*Stigmatopora nigra*	2	3	6	0	0	45.8

Table 4:12 (cont.).

		Abundances					Occurrence (%)
		1	2	3	4	5	
Open lagoons (pre riffle)							
1	*Atherinosoma microstoma*	0	1	2	1	1	62.5
2	*Atherinosoma presbyteroides*	0	2	1	1	0	50.0
	Stigmatopora nigra	0	0	4	0	0	50.0
	Aldrichetta forsteri	0	2	2	0	0	50.0
	Favonigobius tamarensis	1	1	2	0	0	50.0
Bay estuaries, deep (mouth)							
1	*Rhombosolea tapirina*	2	11	4	1	0	75.0
2	*Aldrichetta forsteri*	5	3	3	1	0	50.0
3	*Ammotretis rostratus*	5	6	0	0	0	45.8
4	*Nesogobius sp.2*	2	5	1	0	0	33.3
5	*Atherinosoma presbyteroides*	0	1	6	0	0	29.2
Bay estuaries, deep (mid lower)							
1	*Atherinosoma microstoma*	4	6	8	4	1	50.0
	Rhombosolea tapirina	3	11	9	0	0	50.0
3	*Pseudaphritis urvillii*	9	2	10	1	0	47.8
4	*Aldrichetta forsteri*	3	9	8	1	0	45.7
	Galaxias maculatus	9	8	3	1	0	45.7
Bay estuaries, deep (mid)							
1	*Galaxias maculatus*	2	3	2	1	0	50.0
	Rhombosolea tapirina	2	2	4	0	0	50.0
3	*Retropinna tasmanica*	2	3	1	1	0	43.8
	Pseudaphritis urvillii	3	2	2	0	0	43.8
5	*Atherinosoma presbyteroides*	0	0	2	3	0	31.3
Bay estuaries, deep (mid upper)							
1	*Atherinosoma microstoma*	1	1	1	0	0	75.0
	Rhombosolea tapirina	2	0	1	0	0	75.0
3	*Retropinna tasmanica*	1	1	0	0	0	50.0
4	*Pseudogobius olorum*	0	0	0	1	0	25.0
	Ammotretis rostratus	0	0	1	0	0	25.0
	Aldrichetta forsteri	0	0	1	0	0	25.0

Table 4:12 (cont.).

		Abundances					Occurrence (%)
		1	2	3	4	5	
Bay estuaries, deep (pre-riffle)							
1	*Atherinosoma microstoma*	0	1	1	2	0	80.0
	Galaxias maculatus	1	2	1	0	0	80.0
3	*Retropinna tasmanica*	1	0	2	0	0	60.0
	Pseudaphritis urvillii	0	3	0	0	0	60.0
5	*Atherinosoma presbyteroides*	0	1	1	0	0	40.0
Bay estuaries, flats (mouth)							
1	*Nesogobius sp.2*	0	9	3	0	0	100.00
2	*Atherinosoma presbyteroides*	0	0	5	4	1	83.3
3	*Rhombosolea tapirina*	3	3	3	0	0	75.0
4	*Aldrichetta forsteri*	0	6	2	0	0	66.7
	Ammotretis rostratus	4	4	0	0	0	66.7
Bay estuaries, flats (mid lower)							
1	*Rhombosolea tapirina*	5	3	5	0	0	86.7
2	*Nesogobius sp.2*	2	1	8	0	0	73.3
	Aldrichetta forsteri	2	7	2	0	0	73.3
4	*Atherinosoma presbyteroides*	0	1	4	4	0	60.0
	Torquigener glaber	3	4	2	0	0	60.0
Bay estuaries, flats (mid)							
1	*Aldrichetta forsteri*	0	2	3	0	0	100.00
2	*Favonigobius tamarensis*	0	1	3	0	0	80.0
3	*Atherinosoma microstoma*	0	1	1	1	0	60.0
	Torquigener glaber	0	2	1	0	0	60.0
	Rhombosolea tapirina	1	1	1	0	0	60.0
Bay estuaries, flats (mid upper)							
1	*Aldrichetta forsteri*	0	0	1	0	0	100.00
	Torquigener glaber	0	0	1	0	0	100.00

Table 4:12 (cont.).

		Abundances 1	2	3	4	5	Occurrence (%)
Bay estuaries, flats (pre-riffle)							
1	*Galaxias maculatus*	0	2	0	0	0	66.7
2	*Atherinosoma microstoma*	0	0	1	0	0	33.3
	Pseudogobius olorum	0	0	1	0	0	33.3
Tidal rivers (bar)							
1	*Arripis trutta*	1	2	0	0	0	100.00
2	*Ammotretis liturata*	0	1	0	0	0	33.3
	Ammotretis rostratus	1	0	0	0	0	33.3
	Atherinosoma microstoma	1	0	0	0	0	33.3
	Atherinosoma presbyteroides	1	0	0	0	0	33.3
	Crapatalus arenarius	1	0	0	0	0	33.3
Tidal rivers (mouth)							
1	*Aldrichetta forsteri*	3	3	8	2	0	53.3
2	*Rhombosolea tapirina*	8	5	2	0	0	50.0
	Ammotretis rostratus	8	7	0	0	0	50.0
4	*Atherinosoma microstoma*	1	0	5	0	0	20.0
	Galaxias maculatus	3	2	1	0	0	20.0
Tidal rivers (mid lower)							
1	*Aldrichetta forsteri*	2	4	8	1	1	51.6
	Rhombosolea tapirina	4	7	5	0	0	51.6
3	*Atherinosoma microstoma*	1	3	5	3	0	38.7
4	*Galaxias maculatus*	3	3	3	2	0	35.5
5	*Nesogobius sp.*[2]	5	2	2	1	0	32.3
Tidal rivers (mid)							
1	*Aldrichetta forsteri*	0	1	4	0	0	83.3
	Rhombosolea tapirina	2	1	2	0	0	83.3
3	*Atherinosoma microstoma*	0	1	2	1	0	66.7
	Arripis trutta	0	3	1	0	0	66.7
	Ammotretis rostratus	2	2	0	0	0	66.7

Table 4:12 (cont.).

		Abundances					Occurrence (%)
		1	2	3	4	5	
Tidal rivers (mid upper)							
1	*Galaxias maculatus*	0	0	1	0	0	100.00
	Favonigobius tamarensis	0	0	1	0	0	100.00
Tidal rivers (pre-riffle)							
1	*Galaxias maculatus*	1	1	0	0	0	100.00
Tidal rivers (post-riffle)							
1	*Prototroctes maraena*	1	1	0	0	0	100.00
Tidal creeks (bar)							
1	*Aldrichetta forsteri*	2	1	2	0	0	62.5
	Ammotretis rostratus	4	0	1	0	0	62.5
3	*Rhombosolea tapirina*	1	0	3	0	0	50.0
	Arripis trutta	1	1	2	0	0	50.0
5	*Pseudaphritis urvillii*	1	0	2	0	0	37.5
Tidal creeks (mouth)							
1	*Aldrichetta forsteri*	2	4	4	1	0	52.4
2	*Atherinosoma microstoma*	1	2	3	2	0	38.1
3	*Galaxias maculatus*	1	4	1	0	0	28.6
	Nesogobius sp.2	1	5	0	0	0	28.6
5	*Rhombosolea tapirina*	0	2	3	0	0	23.8
Tidal creeks (mid lower)							
1	*Aldrichetta forsteri*	1	3	4	1	0	64.3
2	*Rhombosolea tapirina*	0	3	4	0	0	50.0
	Pseudaphritis urvillii	2	3	2	0	0	50.0
4	*Atherinosoma microstoma*	1	1	3	0	1	42.9
	Galaxias maculatus	2	1	2	1	0	42.9

Table 4:12 (cont.).

		Abundances 1	2	3	4	5	Occurrence (%)
Tidal creeks (mid)							
1	*Galaxias maculatus*	0	1	3	0	0	50.0
2	*Rhombosolea tapirina*	1	0	1	0	0	25.0
	Atherinosoma microstoma	1	0	1	0	0	25.0
	Pseudaphritis urvillii	1	1	0	0	0	25.0
	Favonigobius tamarensis	2	0	0	0	0	25.0
Tidal creeks (pre-riffle)							
1	*Galaxias maculatus*	0	1	1	0	0	100.00
Tidal Creeks (post-riffle)							
1	*Galaxias maculatus*	0	0	1	0	0	100.00
Tidal tributaries (lower)							
1	*Galaxias maculatus*	0	4	1	0	0	50.0
	Aldrichetta forsteri	1	4	0	0	0	50.0
3	*Atherinosoma microstoma*	0	2	1	1	0	40.0
4	*Favonigobius tamarensis*	1	1	1	0	0	30.0
	Rhombosolea tapirina	2	0	1	0	0	30.0
Tidal tributaries (upper)							
1	*Atherinosoma microstoma*	1	1	2	1	0	50.0
2	*Galaxias maculatus*	0	2	0	2	0	40.0
	Pseudogobius olorum	2	1	1	0	0	40.0
4	*Pseudaphritis urvillii*	1	0	2	0	0	30.0
	Favonigobius tamarensis	0	2	1	0	0	30.0

Table 4:13. Principal species at minor habitats of estuaries based on the percentage occurrence of the species as the most abundant species at the minor habitat. Minor habitat codes follow Table 4:10.

Minor Habitat

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lovettia sealii																				
Prototroctes maraena																				
Retropinna tasmanica							10										11	12	25	20
Galaxias maculatus	33						20		49									24		
Galaxias truttaceus								50												
Ammotretis rostratus									17											
Rhombosolea tapirina				12												27				
Stigmatopora nigra														17	25					
Aldrichetta forsteri				12	17	67						12	14	17		15	11	12	25	
Atherinosoma microstoma	50	59	89	53	17		20					24	36	33	36		20		25	60
Atherinosoma presbyteroides				12						99	69	24	14	13	13	23	20	24		20
Gymnapistes marmoratus																				
Acanthopagrus butcheri		12			17															
Nannoperca australis	17																			
Arripis trutta						33														
Pseudaphritis urvillii					49		10	50	17											
Favonigobius tamarensis															13					
Pseudogobius olorum							20												25	
Tasmanogobius lordi																		12		
Tasmanogobius sp.3							10		17											
Heteroclinus perspicillatus															13					
Torquigener glaber																				
SAMPLE NUMBER	6	17	9	10	6	6	10	2	6	1	16	50	22	24	8	26	45	17	4	5

Species	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Lovettia sealii																14				
Prototroctes maraena												99								
Retropinna tasmanica									17										11	
Galaxias maculatus					50			13		99	50				17	43	99	99	22	33
Galaxias truttaceus																				
Ammotretis rostratus																				
Rhombosolea tapirina		13											36	11					11	
Stigmatopora nigra																				
Aldrichetta forsteri			49				39	29	17					33	33				11	
Atherinosoma microstoma		20	17		50		14	16	17		50		13	28	17	14			22	44
Atherinosoma presbyteroides	42	33	17			25			17							14				
Gymnapistes marmoratus																14				
Acanthopagrus butcheri																				
Nannoperca australis																				
Arripis trutta	25					75							25							
Pseudaphritis urvillii													13						11	11
Favonigobius tamarensis		13	17										13						11	11
Pseudogobius olorum																				
Tasmanogobius lordi																				
Tasmanogobius sp.3															17					
Heteroclinus perspicillatus																				
Torquigener glaber		13		99				32												
SAMPLE NUMBER	12	15	6	1	2	4	28	31	6	1	2	2	8	18	12	7	2	1	9	9

species making similar migrations included *Atherinosoma presbyteroides, Favonigobius lateralis, Nesogobius* sp. 2 and *Torquigener glaber*.

Beach-dammed rivers were characteristically less saline and this may have accounted for the dominance of species tolerant to freshwater such as *Galaxias maculatus, Galaxias truttaceus, Pseudogobius olorum* and *Pseudaphritis urvillii*. In comparison with open bar-dammed systems, open beach-dammed rivers appeared to be be less frequently penetrated by migrant marine species. Most of the latter estuaries, apart from having generally lower salinities, occur on exposed coasts which could limit the number and availability of colonizing species (see Section 4:3:3). In addition, as these sytems are generally open only by shallow channels, access from the sea would be rendered more difficult than for most bar-dammed systems.

Atherinosoma microstoma was also the most abundant species sampled in closed systems (see Table 4:8) followed by *Pseudaphritis urvillii, Galaxias maculatus* and *Acanthopagrus butcheri*.

The bar-ways of open estuaries were not extensively sampled but their fauna appeared to be transitional between those found in marine and estuarine habitats. The faunal characteristics appeared to be more related to the interacting effects of runoff, current strength and turbulence. Estuaries with low runoff entering exposed beaches were dominated numerically by beach species such as *Arripis trutta* (Table 4:13). In contrast, moderate or high runoff systems entering sheltered beaches with poor circulation and flushing exhibited a greater presence of estuarine species such as *Pseudaphritis urvillii, Favonigobius tamarensis* and *Tasmanogobius* sp. 3.

Five species, *Atherinosoma presbyteroides, Aldrichetta forsteri, Nesogobius* sp. 2, *Rhombosolea tapirina* and *Ammotretis rostratus*, occurred most frequently at the mouths of open lagoon and bay estuarine systems. Most of these species remained dominant in mid-lower sections of these estuaries but, in deep bay estuarine systems, estuarine preferring species occurred more frequently. Overall, *Atherinosoma presbyteroides* was the main principal species in bay estuaries and open lagoons but a positional factor was evident. In each case it was clearly more abundant near the entrances of these systems (see also Table 4:12).

The faunas of upper and mid areas of lagoons were similar in composition. *Aldrichetta forsteri* and *Atherinosoma microstoma* occurred most frequently in all areas, while a pipefish, *Stigmatopora nigra*, was also common. *Atherinosoma microstoma* was the most abundant species in this region of the estuary. *Aldrichetta forsteri* occurred frequently in the lower parts of tidal rivers and creeks whilst *Atherinosoma microstoma* replaced *Atherinosoma presbyteroides* as the main 'principal' species. *Rhombosolea tapirina, Pseudaphritis urvillii, Ammotretis rostratus, Nesogobius* sp. 2 and *Galaxias maculatus* were also frequently caught in these habitats. Major components of the lower areas of tidal tributaries were similar to tidal creeks but *Favonigobius tamarensis* replaced *Nesogobius* sp. 2 as the dominant goby.

The upper areas of tidal rivers and creeks were dominated by schools of *Galaxias maculatus*. Similarly, the major species of upper tidal tributaries resembled those occurring in upper tidal creeks.

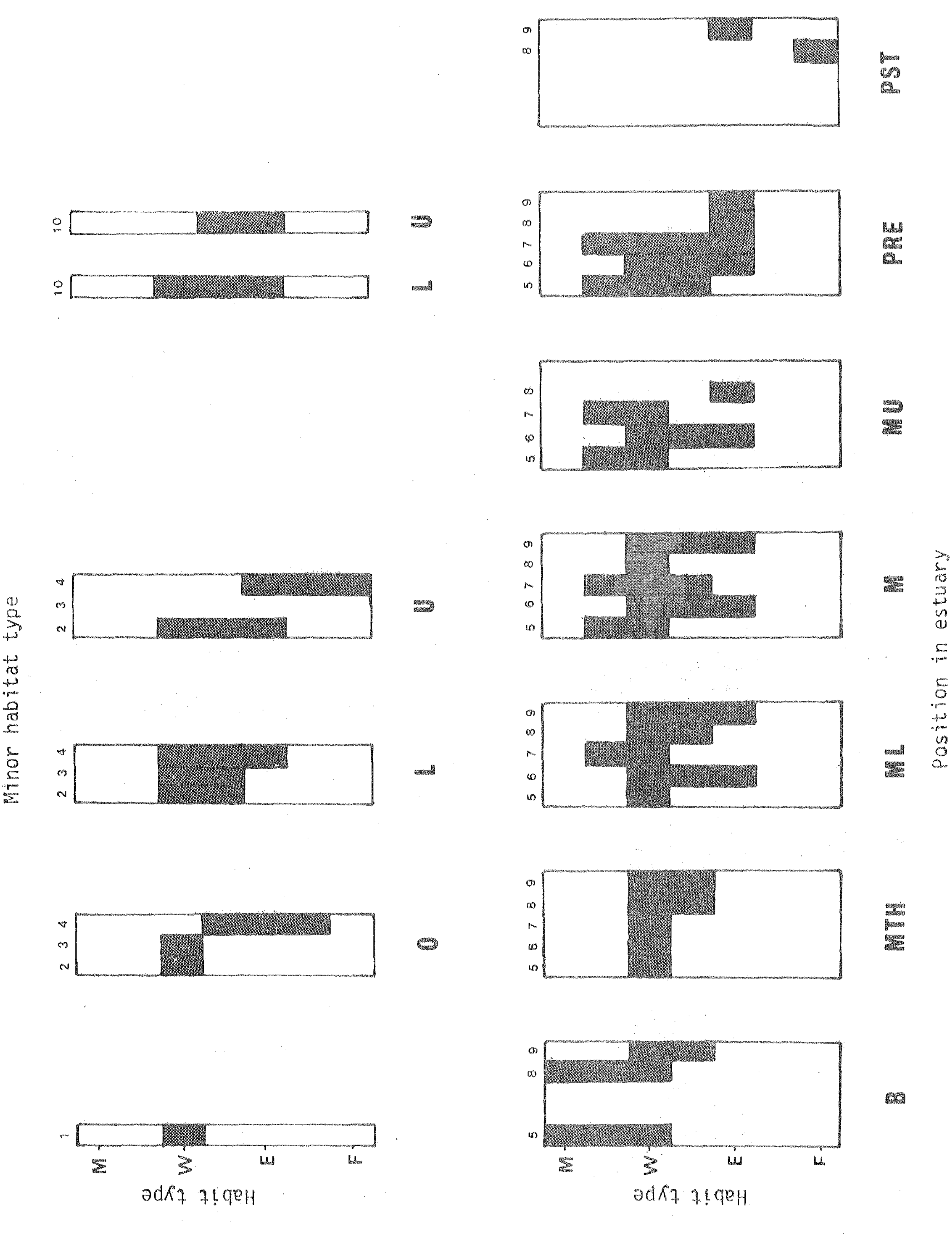
Several major species had widely fluctuating occurrences in bay estuarine systems. Of these, the most notable were a possible preference by *Retropinna tasmanica* for deep bay estuaries and a relatively high occurrence of *Torquigener glaber* over bay estuarine flats.

Comments

Faunal associations within estuarine habitats were isolated, although trends within the data, particularly the B.D.A. analysis, were sometimes difficult to assess.

The fish fauna of Tasmanian estuaries consists basically of 4

Fig. 4:21a. A comparison of the distributions of occurrence dominants by habit categories (i.e. M, marine; W, widespread; E, estuarine; and F, freshwater) in the minor habitat types of estuaries (i.e. 1, coastal lakes; 2, bar-dammed lagoons; 3, bar-dammed rivers; 4, beach-dammed rivers; 5, open lagoons; 6, deep bay estuaries; 7, bay estuarine flats; 8, tidal rivers; 9, tidal creeks; and 10, tidal tributaries). Columns represent the various areas within open estuaries (i.e. B, barway; MTH, entrance; ML, mid-lower areas; M, mid areas; MU, mid-upper areas; PRE, pre-riffle areas; and PST, post-riffle areas) and within closed estuaries and tidal tributaries (i.e. L, lower areas; and U, upper areas); closed estuary types when connected with the sea are represented by column 0. For further explanation of minor habitats see the methods of this section.


Minor habitat type
Habit type
M
W
E
F
1
2 3 4
10
O
L
U
B
MTH
ML
M
MU
PRE
PST
5 6 7 8 9
Position in estuary

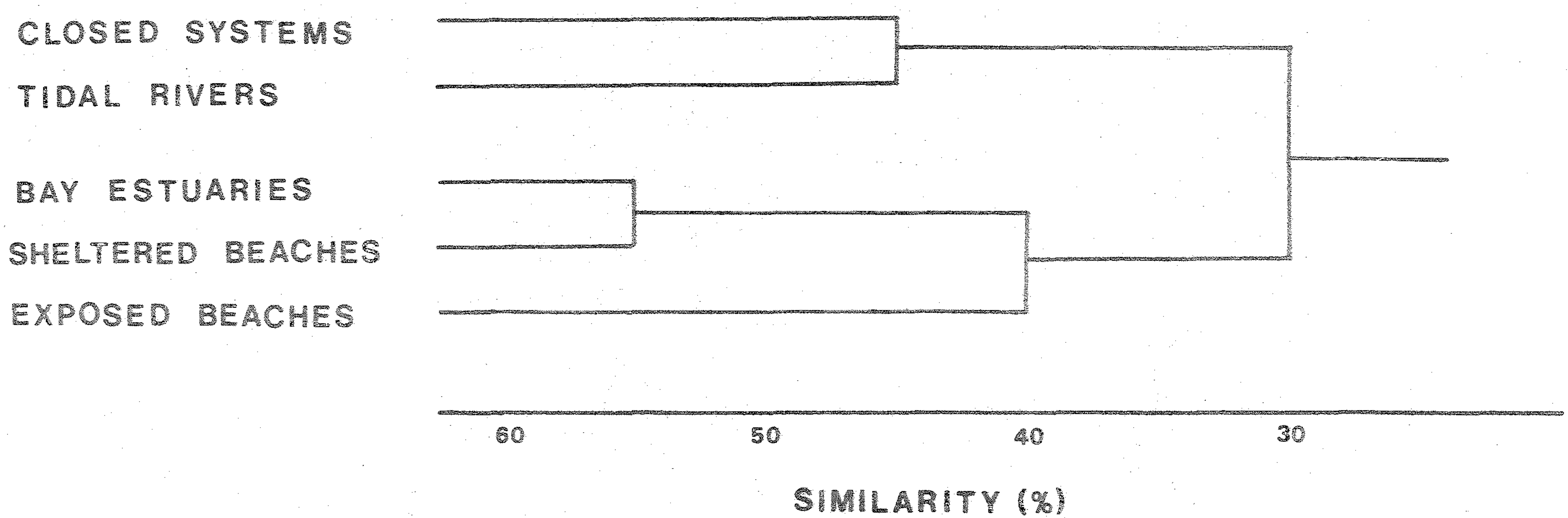


Fig. 4:21b. Similarity in the compositions of fish species occurring at habitat types determined from centroid cluster analysis.

components: a marine component, an estuarine component, a freshwater component and a small group of widespread euryhaline marine fishes. The dominance of each component is largely dependent on the habitat type and the position within the estuary.

The organisation of these components is most clearly depicted from the occurrence and abundance dominants (Fig. 4:21a). Marine species are important only at the barway of open estuaries. The lower regions of these systems are dominated by widespread species although estuarine species were important in tidal rivers and creeks and to some extent in deep bay estuaries. This latter trend mostly persisted in the regions of upper estuaries in varying degrees for each habitat type until, at pre-riffle areas, estuarine components were dominant. Greatest penetration of the widespread component was evident in open lagoons and, of the remaining habitats, 'bay estuarine flats' appeared most similar. These findings question the validity of dividing open estuaries into upper and lower zones in the manner demostrated in Section 4:4:1. Tidal rivers and creeks differ structurally from the other estuary types and should be categorised separately. A repeat of the cluster analysis of major habitat types (see Fig. 4:16) separating open estuaries into 2 new groups, tidal estuaries and bay estuaries/lagoons, supported this argument. Tidal rivers and creeks appeared to be most similar to closed systems whereas bay estuaries were most similar to beach systems (Fig. 4:21b).

Closed estuary types were ordered using the B.D.A. analysis with the fauna of bar-dammed lagoons being most distinct from that of beach-dammed rivers. Bar-dammed systems were dominated by widespread species whereas estuarine/freshwater components were more important in the latter.

The B.D.A. analysis proved only moderately useful in ordinating related minor habitats and groups of species exhibiting similar habitat requirements.

It did, however, along with the occurrence data, provide evidence of more subtle infrastructual trends existing within the fish community. Single species or subgroups of species from the community were clearly more importan at, or totally absent from, some habitat types. Strong preferences by *Torquigener glaber* and *Retropinna tasmanica* for bay estuarine flats and channels are good examples which also applied to several other less abundant species. Such anomalies may be related to specific microhabitat requirements which are controlled by important physical parameters (e.g. salinity, substrate type and tidal position).

4:4:3 Faunal Assemblages of Sheltered Beaches

Methods

The sheltered beach environment is represented by marginal and marine zones. Marginal sheltered beaches consisted of those that (1) received frequent runoff from nearby estuarine systems or (2) became partly brackish only after heavy flooding. Permanently marine sheltered beaches were categorised subjectively into (3) sandy or (4) muddy habitats. A fifth category, tidal arms, related to small, almost totally enclosed, marine embayments.

Twenty-four species had G-statistics greater than the 0.1 level of significance (degrees of freedom = 4, G-statistic = 7.78) (Appendix 4:7). These data were then analysed using Q- and R-mode analyses.

Results and Discussion

Numbers of species

The average number of species per sample varied between 7 and 9.9 and no consistent differences were evident between marginal and marine habitats (Table 4:14). However, comparatively more species in total (relative to the

Table 4:14. Numbers of species collected at minor habitats of sheltered beaches.

	Number of samples	Number of species	Mean number of species per sample
Marginal sheltered beaches (frequent penetration)	26	46	7.2
Marginal sheltered beaches (infrequent penetration)	39	55	9.9
Sheltered sandy beaches	43	55	7.7
Sheltered muddy beaches	15	36	8.7
Tidal arms	22	34	7.0

Table 4:15. Factor loadings from Q-mode binary discriminant analysis of sheltered beach habitat types.

	Factor			
Habitat type	1	2	3	4
Marginal sheltered beaches (frequent penetration)	-.649	-.737	-.038	-.187
Marginal sheltered beaches (infrequent penetration)	-.328	.879	.346	.018
Sheltered sandy beaches	.815	-.305	.173	.462
Sheltered muddy beaches	.141	.299	-.944	.012
Tidal arms	.698	.023	.116	-.706
Variance proportions	.340	.300	.211	.149

numbers of samples) were caught in marginal areas.

Q-mode analysis

The first factor, which accounted for 34% of the variance in the standard residuals matrix, contrasted 'sheltered marine beaches' with 'sheltered marginal zones' (Table 4:15). 'Marginal zones' were correlated negatively with the first factor. 'Sheltered marine beaches' had positive factor loadings and of these 'sheltered sandy beaches' were most highly correlated. The second factor, which accounted for 30% of the variance, primarily contrasted the marginal zones. 'Sheltered beaches penetrated only by floodwaters' were correlated positively; 'beaches penetrated frequently by estuarine runoff' were correlated negatively.

A single habitat group, 'sheltered muddy beaches', loaded heavily on the third factor. This factor accounted for approximately 21% of the variance. Hence, high negative factor scores exhibited by *Lovettia sealii, Hyporhamphus melanochir, Atherinason esox, Atherinosoma microstoma, Acanthaluteres spilomelanurus* and *Nesogobius* sp. 2 suggested a preference for muddy over sandy habitats (Fig. 4:23). Conversely, species with high positive factor scores such as *Leptonotus semistriatus* and *Platycephalus bassensis* have avoided muddy habitats.

The fourth factor, which accounted for the last 15% of the variance in the data matrix, provided a minor contrast between 'sheltered sandy beaches' and 'tidal arms'. *Stigmatopora argus, Atherinosoma presbyteroides, Pseudaphritis urvillii* and *Neoodax balteatus* had the most negative scores on factor 4, and were common in tidal arms. High positive scores on this factor were *Hyporhamphus melanochir, Leptonotus semistriatus, Platycephalus bassensis, Neoodax semifasciatus* and *Penicipelta vittiger.*

R-mode analysis

The first rotated factor contrasted 'sheltered marine beaches' with those 'only exposed to floodwaters'. Eight of the 24 variables were most highly correlated with this factor which accounted for approximately 48% of the standard residuals matrix (Table 4:16). Of these, *Stigmatopora argus, Nesogobius hinsbyi, Lissocampus runa, Atherinason* sp., *Neoodax balteatus* and *Brachaluteres jacksonianus* had high positive factor loadings and, from the factor scores, an affinity to beaches marginal to floodwaters. *Aldrichetta forsteri* and *Contusus* sp. had high negative correlations and exhibited a greater association for marine sheltered beaches than marginal areas.

The second rotated factor, which accounted for a further 31% of the variance, contrasted 'sheltered beaches exposed to frequent freshwater runoff' with two minor habitats, 'sheltered sandy beaches' and 'tidal arms'. The dominant score on the second factor was negative and characterised the marginal zone. Five species showed affinities for this habitat: *Syngnathus tuckeri, Sillago bassensis, Tasmanogobius lordi, Favonigobius tamarensis* and *Pseudaphritis urvillii*. Highest positive loadings were obtained for *Atherinosoma presbyteroides, Neoodax semifasciatus* and *Penicipelta vittiger* These species were least frequently occurring or absent at marginal areas receiving frequent runoff and most common at sheltered sandy beaches and tidal arms.

Six species were most highly correlted with the third rotated factor. All loadings were positive and this was associated with the high positive score observed for 'sheltered muddy beaches'. The correlated species were *Lovettia sealii, Atherinosoma microstoma, Atherinason esox, Acanthaluteres spilomelanurus, Nesogobius* sp. 2 and *Hyporhamphus melanochir*. Moderately high loadings on the second factor for the last 4 species suggested that they also occurred frequently in other sheltered marine habitats.

Table 4:16. Factor loadings, variance proportions, and factor scores for rotated factors based on sheltered beach habitats.

Code No.	Species	Factor 1	2	3	4
1	*Stigmatopora argus*	.985	-.045	.153	-.062
2	*Nesogobius hinsbyi*	.968	-.022	.108	.226
3	*Lissocampus runa*	.936	.107	.179	.285
4	*Atherinason sp.*	.893	.204	.008	.401
5	*Neoodax balteatus*	.859	.311	.392	-.107
6	*Brachaluteres jacksonianus*	.740	.070	.652	.149
7	*Aldrichetta forsteri*	-.990	.006	-.073	.120
8	*Contusus sp.*	-.855	.345	-.387	.030
9	*Atherinosoma presbyteroides*	.297	.955	-.013	-.010
10	*Neoodax semifasciata*	-.470	.739	-.164	.454
11	*Penicipelta vittiger*	.029	.699	-.254	.668
12	*Syngnathus tuckeri*	-.116	-.951	-.275	-.081
13	*Sillago bassensis*	-.116	-.951	-.275	-.081
14	*Tasmanogobius lordi*	-.239	-.947	.124	-.178
15	*Favonigobius tamarensis*	.268	-.939	-.212	.036
16	*Pseudaphritis urvilli*	.362	-.878	-.281	-.141
17	*Lovettia sealii*	.257	.003	.965	-.059
18	*Atherinosoma microstoma*	.136	-.170	.953	-.210
19	*Hyporhamphus melanochir*	-.142	.493	.800	.312
20	*Atherinason esox*	.474	.414	.749	.208
21	*Acanthaluteres spilomelanurus*	.422	.524	.739	-.037
22	*Nesogobius sp.2*	.243	.653	.714	-.067
23	*Platycephalus bassensis*	.688	-.102	.130	.707
24	*Leptonotus semistriatus*	.579	.411	.016	.704
Variance proportions		.476	.313	.156	.055
			Factor Scores		
Marginal sheltered beaches (frequent penetration)		-.17	-1.68	-.60	.01
Marginal sheltered beaches (infrequent penetration)		1.63	.25	.19	.66
Sheltered sandy beaches		-1.01	.78	-.55	1.13
Sheltered muddy beaches		-.54	-.07	1.67	-.33
Tidal arms		.08	.72	-.71	-1.47

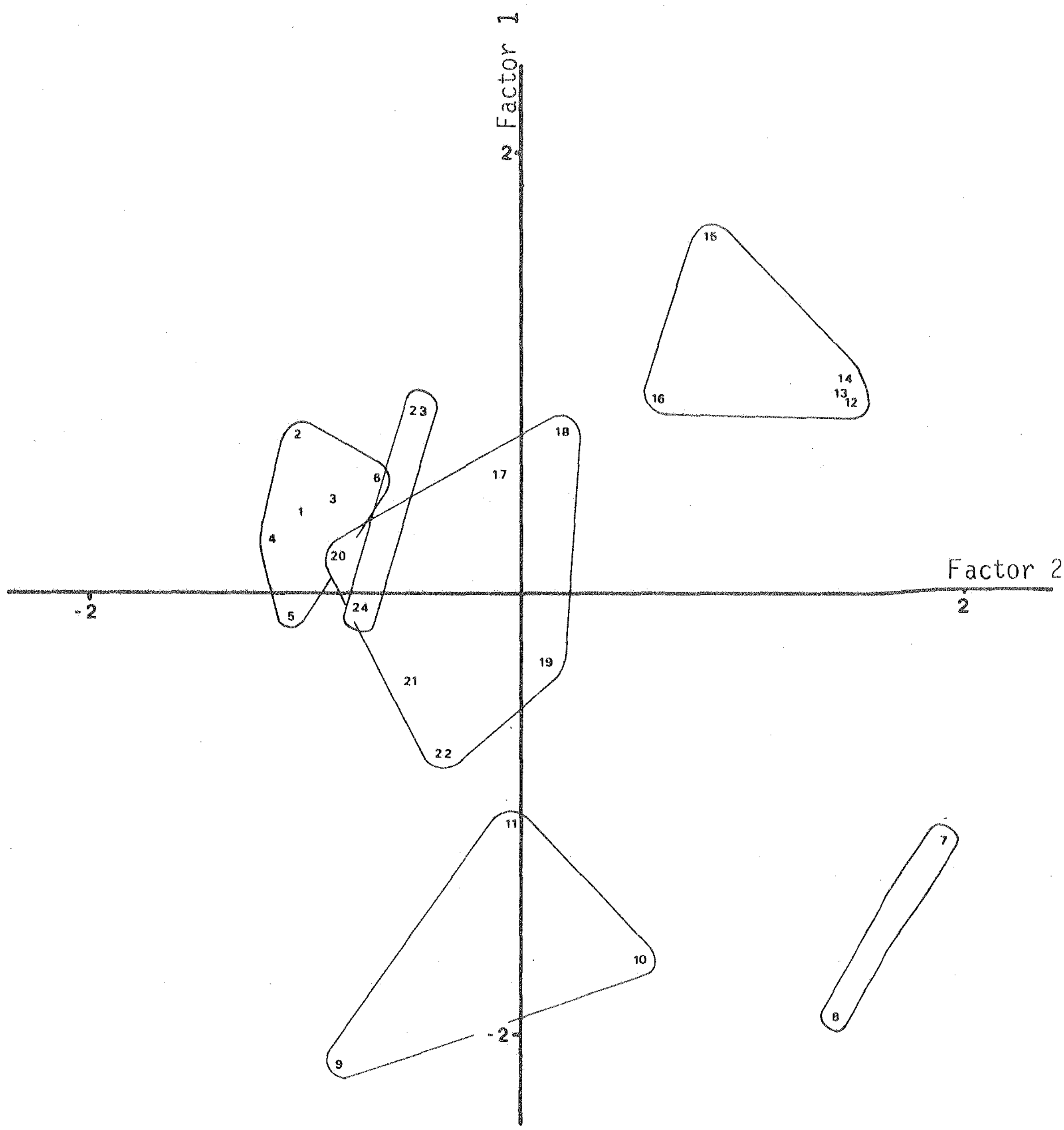


Fig. 4:22. Fish species from sheltered beach habitats plotted by factor scores on Factors 1 and 2 of Q-mode binary discriminant analysis. Species numbers are coded and assembled according to Table 4:16.

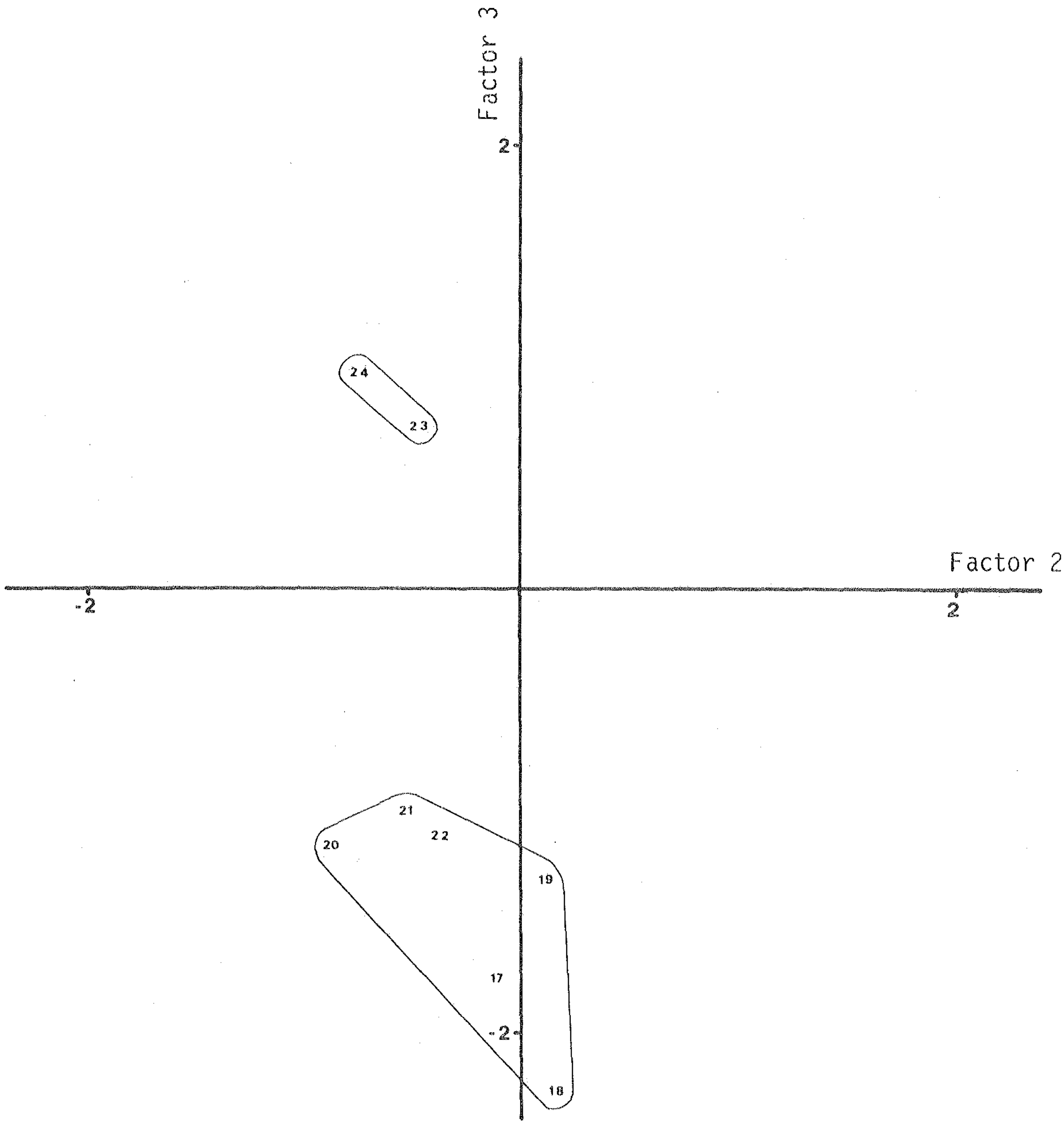


Fig. 4:23. Some fish species from sheltered beach habitats plotted by factor scores on Factors 2 and 3 of Q-mode binary discriminant analysis. Species are coded and assembled according to Table 4:16.

The final 5% of the variance in the data matrix was encompassed in the fourth factor. Primarily, the factor served to isolate species that preferred sheltered sandy beaches and avoided tidal arms. Highly positively correlated species, *Platycephalus bassensis* and *Leptonotus semistriatus*, were collected from beaches but were absent from tidal arm samples. This preference-avoidance trend in also evident from the factor scores.

A plot of scores after varimax rotation on the first two factors of the Q-mode analysis is given in Fig. 4:22. The species groups abtained from R-mode analysis were clustered and those with opposing signs on the factor loadings were contrasted. In summary, R-mode factor 1 groups were separated on both Q-mode factors while R-mode factor 2 groups were separated on the first Q-mode factor. The remaining R-mode groups were not discriminated on these factors.

Occurrence and abundance of species

Most frequently occurring species from each minor habitat were ranked in Table 4:17.

Sandy marine habitats of tidal arms and sandy beaches were characterised by 5 widespread species: *Atherinosoma presbyteroides* (dominant), *Rhombosolea tapirina*, *Nesogobius* sp. 2, *Aldrichetta forsteri* and *Ammotretis rostratus*. *Atherinosoma microstoma*, which was a major component of estuarine faunas, was common on muddy beaches where *Atherinosoma presbyteroides* occurred less frequently than in other totally marine habitats.

Common species at the marginal habitats were similar to those of non-marginal habitats. *Atherinosoma presbyteroides* was dominant on flood penetrated beaches but *Acanthaluteres spilomelanurus* was also commonly sampled. Faunas of beaches frequently influenced by runoff from nearby estuaries were dominated by *Rhombosolea tapirina* and *Aldrichetta forsteri*, which also were the most common species occurring at the mouths of deep bay estuaries.

Table 4:17. Ranking by occurrence of the most common species from each minor habitat from the sheltered beaches. Abundances of species were classed as follows: (1) 1, 2; (2) 3 - 9; (3) 10 - 99; (4) 100 - 999 and; (5) greater than 1000 individuals in a sample.

		Abundances					Occurrence (%)
		1	2	3	4	5	
Sheltered beaches, marginal (frequent penetration)							
1	*Rhombosolea tapirina*	7	13	2	0	0	84.6
2	*Aldrichetta forsteri*	2	8	5	1	0	61.5
3	*Nesogobius sp.2*	0	2	11	2	0	57.7
4	*Atherinosoma presbyteroides*	1	2	8	2	1	53.8
5	*Arripis trutta*	3	4	2	1	0	38.5
Sheltered beaches, marginal (infrequent penetration)							
1	*Atherinosoma presbyteroides*	3	3	13	14	1	87.2
2	*Nesogobius sp.2*	4	10	15	3	0	82.1
3	*Rhombosolea tapirina*	5	12	8	0	0	64.1
4	*Ammotretis rostratus*	8	9	5	0	0	56.4
5	*Acanthaluteres spilomelanurus*	2	4	11	3	0	51.3
Sheltered beaches, sandy							
1	*Atherinosoma presbyteroides*	2	6	18	8	2	83.7
2	*Nesogobius sp.2*	5	9	17	1	0	74.4
3	*Aldrichetta forsteri*	5	13	10	3	0	72.1
4	*Rhombosolea tapirina*	3	9	14	0	0	60.5
5	*Ammotretis rostratus*	3	10	7	0	0	46.5

Table 4:17 (cont.).

		Abundances					Occurrence (%)
		1	2	3	4	5	
Sheltered beaches, muddy							
1	*Nesogobius sp.2*	1	2	7	4	0	93.3
2	*Rhombosolea tapirina*	1	5	6	0	0	80.0
3	*Atherinosoma presbyteroides*	1	1	6	3	0	73.3
	Atherinosoma microstoma	0	5	5	1	0	73.3
5	*Aldrichetta forsteri*	3	3	3	1	0	66.7
Tidal arms							
1	*Atherinosoma presbyteroides*	1	2	7	8	2	90.9
2	*Rhombosolea tapirina*	2	5	11	0	0	81.8
3	*Nesogobius sp.2*	0	4	12	1	0	77.3
4	*Aldrichetta forsteri*	0	5	5	2	0	54.5
5	*Ammotretis rostratus*	3	7	0	0	0	45.5

Table 4:18 : Principal species at minor habitats of beaches based on the percentage occurrence of the species as the most abundant species at the minor habitat. Minor habitat codes follow Tables for exposed and sheltered beaches respectively.

Sheltered Beaches

Species	Minor Habitat 1	2	3	4	5
Ammotretis rostratus	12				
Aldrichetta forsteri	12		19		
Atherinosoma microstoma				20	
Atherinosoma presbyteroides	19	55	40	27	59
Nesogobius sp. 2	15	13	16	27	
Sample number	26	40	43	15	22

Exposed Beaches

Species	Minor Habitat 1	2	3	4	5	6	7	8	9	10
Hyporhamphus melanochir					11					
Ammotretis liturata								67	21	33
Stigmatopora argus					11					
Aldrichetta forsteri	18		23	21	33	11	50			
Atherinosoma presbyteroides	24		16		32	21				
Arripis trutta	47	99	29	50		41			29	67
Crapatalus arenarius								33	29	
Nesogobius sp. 2					22		50			
Sample number	17	31	3	28	9	44	2	3	24	3

Arripis trutta had a higher ranking at this marginal zone.

Atherinosoma presbyteroides was the numerically dominant species at all minor habitat types (Table 4:18). Only 4 other species, *Ammotretis rostratus, Aldrichetta forsteri, Atherinosoma microstoma* and *Nesogobius* sp. 2, were dominant in greater than 10% of samples at any minor habitat type.

Comments

The B.D.A. analysis provided evidence of trends within the data. Marginal sheltered beaches possessed a fauna that was predominantly marine but possessed some estuarine elements. Species favouring estuarine conditions, such as *Pseudaphritis urvillii, Favonigobius tamarensis, Galaxias maculatus* and *Amoya bifrenatus* (see Section 4:4:1), only occurred in marginal areas of sheltered beaches. *Syngnathus tuckeri,* which has been shown to prefer more exposed beaches (see Section 4:4:1), was rather surprisingly sampled several times in this habitat.

The roles of abundance and occurrence dominants of marine sheltered and marginal sheltered beaches alike were controlled totally by widespread species. Some other species, however, were clearly more common at sandy habitats than muddy habitats and vice versa, while other moderately common species were totally absent from one or more minor habitats. This suggests that secondary species, rather than dominant species, may be important in isolating differences in macrohabitat complexity.

4:4:4 Faunal Assemblages of Exposed Beaches

Methods

Exposed and semi-exposed beaches were both categorised into marginal and marine areas. Marginal areas were then regrouped into those receiving frequent penetration of brackish waters and those only influenced by flood

Table 4:19. Numbers of species collected at minor habitats of exposed beaches.

	Number of samples	Number of species	Mean number of species per sample
Marginal semi-exposed beaches (frequent penetration)	20	27	4.3
Marginal semi-exposed beaches (infrequent penetration)	30	30	3.8
Semi-exposed beaches (geological protection)	28	26	3.9
Semi-exposed beaches (biophysical protection)	9	23	5.0
Semi-exposed beaches (wave refraction)	42	28	3.8
Semi-exposed beaches (partial protection)	2	9	6.0
Marginal exposed beaches (frequent penetration)	3	5	2.7
Exposed beaches (continuous swells)	3	3	1.7
Exposed beaches (non-continuous swells)	22	10	2.1
Exposed beaches (wave refraction)	3	4	2.7

waters. Exposed beaches of the latter type were not encountered.

Semi-exposed beaches were categorized into minor habitats according to whether incident wave enery was reduced or increased. Oceanic beaches can experience partial protection from geological (e.g. promontories, headlands, reefs etc.) or biophysical obstacles (e.g. kelp beds or seagrass stands). Non-oceanic beaches, or those enclosed in large bays or channels, can still receive direct, but often reduced, oceanic wave energy and are hence referred to as receiving partial protection. Likewise, some beaches in bays can be totally protected from direct swells but receive consistent energy by wave refraction or reflection.

Exposed beaches were categorized into 3 weak categories designated by the following: beaches on coasts facing the prevailing weather where heavy swells are almost continuous; beaches on coasts not facing the prevailing weather where swells are generally lighter and less continuous (non-continuous); and partly protected beaches that receive moderate and continuous swells from wave refraction.

Seven species had G-statistics greater than the 0.1 level of signifcance (degrees of freedom = 9, G-statistic = 14.68) (Appendix 4:7). These data were then analysed using Q- and R- mode analyses.

Results and Discussion

Numbers of species

Total numbers of species and the mean number of species per sample for each type of minor habitat are given in Table 4:19.

The average number of species per sample was consistently higher for semi-exposed beach samples than for exposed beaches samples. A similar trend was apparent for the total number of species caught at each minor habitat type. Semi-exposed beaches with partial and biophysical protection appeared to have the most 'diverse' faunas.

Table 4:20. Factor loadings from Q-mode binary discriminant analysis of exposed habitat types.

Habitat type	Factor 1	2	3	4
Marginal semi-exposed beaches (frequent penetration)	-.679	-.278	-.385	-.543
Marginal semi-exposed beaches (infrequent penetration)	.539	.558	-.628	.028
Semi-exposed beaches (geological protection)	-.078	.708	.511	-.440
Semi-exposed beaches (biophysical protection)	-.712	-.546	.333	.251
Semi-exposed beaches (wave refraction)	.289	.904	.148	.204
Semi-exposed beaches (partial protection)	-.875	.118	-.004	.210
Marginal exposed beaches (frequent penetration)	.995	.060	-.022	.078
Exposed beaches (continuous swells)	.772	-.500	.365	-.104
Exposed beaches (non-continuous swells)	.665	-.657	-.260	.025
Exposed beaches (wave refraction)	.921	-.238	-.239	-.138
Variance proportions	.499	.276	.120	.067

Q-mode analysis

Factor loadings for each minor habitat are given in Table 4:20.

The first factor accounted for 50% of the variance in the data matrix. 'Exposed marine' and 'marginal beaches penetrated only by flood waters' had high positive loadings on this factor. *Arripis trutta* and *Crapatalus arenarius* had high positive scores and best characterised these habitats (Fig. 4:24). Most semi-exposed habitats had negative factor loadings with 'partial' and 'biophysical protection' highest. *Atherinosoma presbyteroides* occurred more frequently in these areas although *Arripis trutta* was the dominant species in marginal areas.

Trends within the second factor were difficult to interpret. High negative factor scores for *Stigmatopora argus* and *Acanthaluteres spilomelanurus* were certainly derived from a negative factor loading for biophysically protected beach habitats (see Table 4:22). Similarly, moderately negative loadings for exposed beaches where swells are not continuous were responsible for high scores for *Crapatalus arenarius; Stigmatopora argus* and *Acanthaluteres spilomelanurus* avoided this minor habitat.

The third factor accounted for 12% of the variance. From the factor scores, two negative species, *Ammotretis rostratus* and *Crapatalus arenarius*, and two positive species, *Arripis trutta* and *Nesogobius* sp. 2, appeared to be contrasted by 'semi-exposed beaches receiving floodwater exposure' with 'physically protected exposed beaches'. Apart form *Nesogobius* sp. 2 these were among the 5 most frequently occurring species at both habitat types. As *Nesogobius* sp. 2, which was common at lower estuarine and sheltered habitats, was not collected from the physically protected, semi-exposed beaches, its absence here is notable.

Correlations on the last factor were difficult to determine and much of the variance was possibly due to sampling variation.

Table 4:21. Factor loadings, variance proportions and factor scores for rotated factors based on exposed beach habitats.

Code No.	Species	Factor 1	Factor 2
1	*Stigmatopora argus*	.922	.124
2	*Acanthaluteres spilomelanurus*	.916	.209
3	*Nesogobius sp. 2*	.908	.262
4	*Arripis trutta*	-.799	.102
5	*Ammotretis rostratus*	-.393	.858
6	*Atherinosoma presbyteroides*	.451	.785
7	*Crapatalus arenarius*	-.505	-.657
Variance proportions		.581	.231

	Factor Scores 1	Factor Scores 2
Marginal semi-exposed beaches (frequent penetration)	.548	.799
Marginal semi-exposed beaches (infrequent penetration)	-.892	.326
Semi-exposed beaches (geological protection)	-.380	.564
Semi-exposed beaches (biophysical protection)	2.497	.072
Semi-exposed beaches (wave refraction)	-.961	1.143
Semi-exposed beaches (partial protection)	.318	.969
Marginal exposed beaches (infrequent penetration)	-.588	-.286
Exposed beaches (continuous swells)	-.108	-.641
Exposed beaches (non-continuous swells)	-.064	-2.127
Exposed beaches (wave refraction)	-.371	-.818

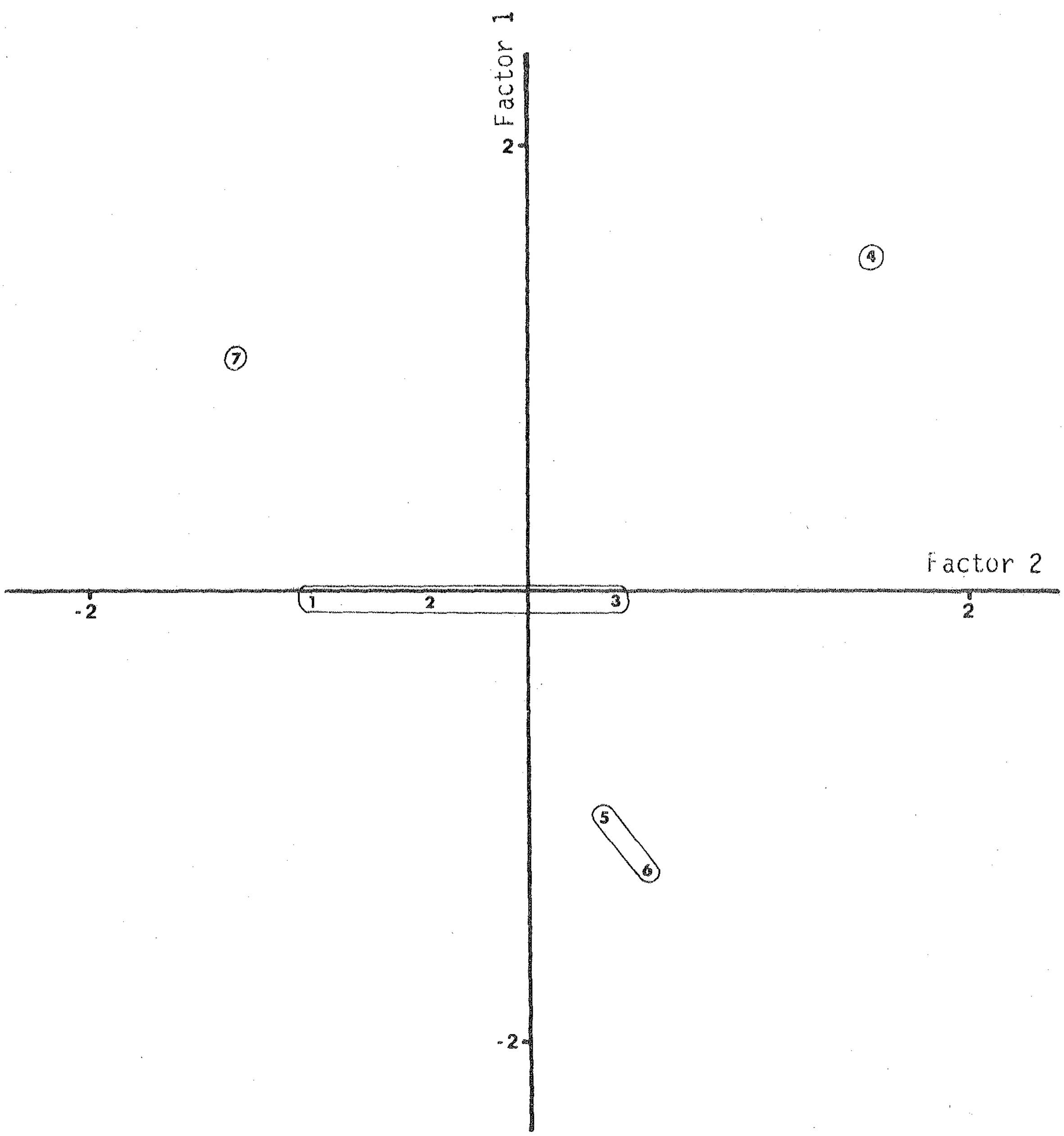


Fig. 4:24. Fish species from exposed beaches plotted by factor scores on Factors 1 and 2 of Q-mode binary discriminant analysis. Species are coded and assembled according to Table 4:21.

R-mode analysis

The first rotated factor, which accounted for 58% of the variance in the data matrix, was most highly correlated with 4 species (Table 4:21). From the factor score matrix, those species with high positive loadings such as *Stigmatopora argus*, *Nesogobius* sp. 2 and *Acanthaluteres spilomelanurus* were clearly linked with biophysically protected beaches.

Arripis trutta alone exhibited a high negative correlation with this factor. All remaining habitats exhibited negative factor scores which reflected the dominance of the species in most exposed beach habitats.

A further 23% of the variance was accounted for by the second rotated factor which segregated 3 species: *Crapatalus arenarius*, *Ammotretis rostratus* and *Atherinosoma presbyteroides*. As indicated by the factor scores, the relative occurrence of these 3 species served to contrast negatively scored exposed beach habitats with positively scored semi-exposed beach habitats. *Crapatalus arenarius* was more common on exposed beaches than semi-exposed beaches whereas the converse was true for *Ammotretis rostratus* and *Atherinosoma presbyteroides*.

A plot of scores on the first 2 factors from the Q-mode analysis (see Fig. 4:24) supported the above results. The 4 species groups obtained from the R-mode analysis were clearly discriminated. The second factor identified 2 species, *Arripis trutta* and *Crapatalus arenarius*, which typified exposed beaches; the first factor identified the remaining species which were basically more common on semi-exposed beaches.

Occurrence and abundance of species

Ranked occurrences of species for each minor habitat are given in Table 4:22.

Arripis trutta was the dominant species at most minor habitats whilst *Aldrichetta forsteri*, *Ammotretis rostratus*, *Ammotretis liturata*, *Atherinosoma*

Table 4:22. Ranking by occurrence of the most common species from each minor habitat type from the exposed beaches. Abundances of species were classed as follows: (1) 1, 2; (2) 3 - 9; (3) 10 - 99; (4) 100 - 999 and; (5) greater than 1000 individuals in a sample.

		Abundances					Occurrence (%)
		1	2	3	4	5	
Semi-exposed beaches, marginal (frequent penetration)							
1	*Arripis trutta*	4	11	4	0	0	63.3
2	*Aldrichetta forsteri*	4	6	8	0	0	60.0
3	*Ammotretis rostratus*	9	1	2	0	0	40.0
4	*Crapatalus arenarius*	9	2	0	0	0	36.7
5	*Atherinosoma presbyteroides*	0	1	6	0	0	23.3
Exposed beaches, marginal (frequent penetration)							
1	*Arripis trutta*	0	1	1	1	0	100.0
Semi-exposed beaches, marginal (infrequent penetration)							
1	*Arripis trutta*	2	4	6	0	0	60.0
2	*Atherinosoma presbyteroides*	0	4	6	0	0	50.0
3	*Aldrichetta forsteri*	3	3	3	0	0	45.0
4	*Crapatalus arenarius*	4	4	0	0	0	40.0
5	*Ammotretis rostratus*	2	5	0	0	0	35.0
Semi-exposed beaches (geological protection)							
1	*Arripis trutta*	4	4	11	1	0	71.4
2	*Aldrichetta forsteri*	5	5	7	1	0	64.3
3	*Atherinosoma presbyteroides*	1	5	4	0	0	35.7
4	*Ammotretis rostratus*	3	5	0	0	0	28.6
5	*Crapatalus arenarius*	6	1	0	0	0	25.0

Table 4:22 (cont.).

		Abundances 1	2	3	4	5	Occurrence (%)
Semi-exposed beaches (biophysical protection)							
1	*Aldrichetta forsteri*	2	1	2	1	0	66.7
	Nesogobius sp.2	0	3	3	0	0	66.7
3	*Atherinosoma presbyteroides*	0	1	2	1	0	44.4
4	*Acanthaluteres spilomelanurus*	0	2	1	0	0	33.3
5	*Stigmatopora argus*	0	1	1	0	0	22.2
Semi-exposed beaches (wave refraction)							
1	*Arripis trutta*	5	9	14	3	0	73.8
2	*Aldrichetta forsteri*	6	10	9	0	0	59.5
3	*Ammotretis rostratus*	8	8	1	0	0	40.5
4	*Ammotretis liturata*	5	7	2	0	0	33.3
5	*Atherinosoma presbyteroides*	0	1	7	3	0	26.2
Semi-exposed beaches (partial protection)							
1	*Aldrichetta forsteri*	0	1	1	0	0	100.0
	Atherinosoma presbyteroides	0	1	1	0	0	100.0
3	*Rhombosolea tapirina*	0	0	1	0	0	50.0
	Nesogobius sp.2	0	0	1	0	0	50.0
	Atherinosoma microstoma	0	1	0	0	0	50.0
	Diodon nicthemerus	0	1	0	0	0	50.0
Exposed beaches (continuous swells)							
1	*Ammotretis liturata*	1	1	0	0	0	66.7
	Arripis trutta	1	1	0	0	0	66.7

Table 4:22 (cont.).

		Abundances 1	2	3	4	5	Occurrence (%)
Exposed beaches (non-continuous swells)							
1	*Arripis trutta*	2	4	4	1	0	50.0
	Crapatalus arenarius	5	4	2	0	0	50.0
3	*Aldrichetta forsteri*	5	3	1	0	0	40.9
4	*Ammotretis liturata*	4	2	0	0	0	27.3
5	*Ammotretis rostratus*	1	0	1	0	0	9.1
Exposed beaches (wave refraction)							
1	*Arripis trutta*	0	1	2	0	0	100.0

presbyteroides and *Crapatalus arenarius* were the only other frequently occurring species.

The most diverse semi-exposed beach types (partial and biophysical protection) had faunas that were more typical of sheltered habitats (e.g. *Nesogobius* sp. 2, *Acanthaluteres spilomelanurus, Rhombosolea tapirina* and *Atherinosoma microstoma*). *Arripis trutta* was not amongst the 5 most frequently occurring species in these minor habitats.

Principal species at exposed and semi-exposed minor habitats were schooling species *Arripis trutta, Aldrichetta forsteri* and *Atherinosoma presbyteroides* (see Table 4:18). The relative importance of burrowing species, *Ammotretis liturata* and *Crapatalus arenarius*, however, was greater at totally exposed habitats.

Comments

The B.D.A. analysis, when used in conjunction with occurrence and abundance data, proved useful in isolating faunal relationships. Two semi-exposed beach categories, 'partial' and biophysical protection', had faunas that more closely resembled those of sheltered beaches than those of exposed habitats. Due to reduced wave activity, these minor habitats had permanently attached vegetation leading to the establishment of a weed-dwelling component to the fauna. They may be transitory between sheltered and semi-exposed habitats.

The fish fauna of exposed beaches appeared to be similar in composition but less diverse than that of semi-exposed beaches. Burrowing species, which are capable of avoiding a continuous buffeting by swells, were major components of the fish community on high energy coasts. Widespread species, particularly *Arripis trutta*, were also important in abundance and occurrence dominance rankings.

4:5 ASSOCIATION OF SPECIES WITH PHYSICAL PARAMETERS

The relationship between species composition and 3 important physical parameters of habitats, namely salinity, substrates and tides, are examined below.

4:5:1 Salinity Effects

Methods

Occurrence data for species was re-ordered into salinity classes which were defined by the classification of brackish, marine and hypersaline waters (see Table 2:1). Consequently, classes represented in the following analyses included (1) $1^{0}/oo$; (2) 1 - $5^{0}/oo$; (3) 5 - $18^{0}/oo$; (4) 18 - $30^{0}/oo$; (5) 30 - $36^{0}/oo$; (6) 36 - $45^{0}/oo$; and (7) greater than $45^{0}/oo$. Data from sampling sites that had either a distinct salt wedge or a salt gradient transversing 2 classes were omitted because the salinity layer from which each species came could not be determined.

A summary of the salinity distributions of species, their probable salinity status and their G-statistics are given in Appendix 4:9. Species with G-statistics less than 12.59, the 0.05 significance level with 6 degrees of freedom, were not included in the B.D.A. analysis.

Results and Discussion

Q-mode analysis

The first factor which accounted for 53% of the variance, contrasted marine conditions with all other salinity ranges (Table 4:23). This result was not surprising because more species occurred in marine habitats than in brackish or hypersaline environments (see Section 4:4:1).

Hypersaline areas were most highly correlated with the second factor.

Table 4:23. Factor loadings from Q-mode binary discriminant analysis of the salinity characteristics of habitats.

	Factor			
Salinity range	1	2	3	4
less than $1^{0}/oo$	.749	.123	-.574	-.089
1 - 5 "	.846	.166	-.332	.087
5 - 18 "	.905	.178	.212	.125
18 - 30 "	.513	.234	.799	-.066
30 - 36 "	-.974	-.201	-.051	.002
36 - 45 "	.355	-.864	.077	.332
greater than $45^{0}/oo$	.541	-.745	.058	-.372
Variance proportions	.533	.210	.163	.040

Aldrichetta forsteri, Scorpaena ergastulorum and *Neoodax balteatus* were sampled from a bar-dammed lagoon with a salinity of $40.6^{0}/oo$ but only *Atherinosoma microstoma* occurred in hyperhaline (II) waters. This species was common in hypersaline saltpans where salinities to $74^{0}/oo$ were recorded.

The third factor, which occupied 16% of the variance, contrasted polyhaline and freshwater/oligohaline environments and may isolate true estuarine and stenohaline freshwater species.

The fourth and fifth factors each accounted for less than 5% of the variance and were not closely correlated with any variable.

R-mode analysis

The importance of the first rotated factor as a group discriminator was evident from its large variance proportion (approximately 80%). High positive correlations with this factor for 19 or the 39 species included in the analysis (Table 4:24) were linked with a preference for marine

Table 4:24. Factor loadings, variance proportions and factor scores for rotated factors based on salinity characteristics.

Code No.	Species	Factor 1	2	3
1	*Penicipelta vittiger*	.935	.349	.054
2	*Syngnathus tuckeri*	.935	.349	.055
3	*Neoodax semifasciata*	.935	.348	.054
4	*Crapatalus arenarius*	.911	.404	.063
5	*Ammotretis liturata*	.902	.423	.066
6	*Hyporhamphus melanochir*	.899	.436	-.005
7	*Crapatalus sp.*	.898	.414	.125
8	*Heteroclinus perspicillatus*	.887	.458	.026
9	*Syngnathus phillipi*	.876	.481	-.036
10	*Atherinason esox*	.875	.480	.038
11	*Cristiceps australis*	.872	.485	.037
12	*Acanthaluteres spilomelanurus*	.856	.516	.034
13	*Meuschenia freycineti*	.831	.483	.039
14	*Neoodax balteatus*	.831	.436	.075
15	*Contusus sp.*	.777	.613	-.139
16	*Ammotretis rostratus*	.750	.623	-.082
17	*Stigmatopora argus*	.749	.660	-.035
18	*Platycephalus bassensis*	.719	.692	-.047
19	*Contusus richei*	.711	.696	.047
20	*Favonigobius tamarensis*	-.968	.219	.059
21	*Pseudaphritis urvillii*	-.930	-.250	.202
22	*Anguilla australis*	-.918	-.194	-.114
23	*Pseudogobius olorum*	-.899	.042	.431
24	*Atherinosoma microstoma*	-.870	.189	.327
25	*Tasmanogobius sp. 3*	-.805	-.419	.207
26	*Retropinna tasmanica*	-.803	-.319	.484
27	*Torquigener glaber*	.076	.989	-.079
28	*Rhombosolea tapirina*	-.045	.965	.207
29	*Stigmatopora nigra*	.280	.953	-.083
30	*Nesogobius sp. 2*	.305	.945	-.111
31	*Nesogobius hinsbyi*	.403	.873	-.274
32	*Aldrichetta forsteri*	.480	.852	.186
33	*Arripis trutta*	.697	.712	.063

Table 4:24 (cont.).

Code No.	Species	Factor 1	2	3
34	*Atherinason sp.*	.665	.711	-.226
35	*Atherinosoma presbyteroides*	.680	.707	.124
36	*Gymnapistes marmoratus*	.610	.675	.386
37	*Galaxias truttaceus*	-.231	-.938	.077
38	*Prototroctes maraena*	-.157	-.888	-.405
39	*Galaxias maculatus*	-.590	-.785	.025
	Variance proportions	.804	.144	.029

	Factor Scores		
less than $1^{o}/oo$	.074	-1.682	-1.115
1 - 5 "	-.004	-.562	.439
5 - 18 "	-.773	-.100	1.838
18 - 30 "	-1.373	1.347	-1.083
30 - 36 "	1.868	1.015	.013
36 - 45 "	.125	-.004	.023
greater than $45^{o}/oo$	.083	-.016	-.114

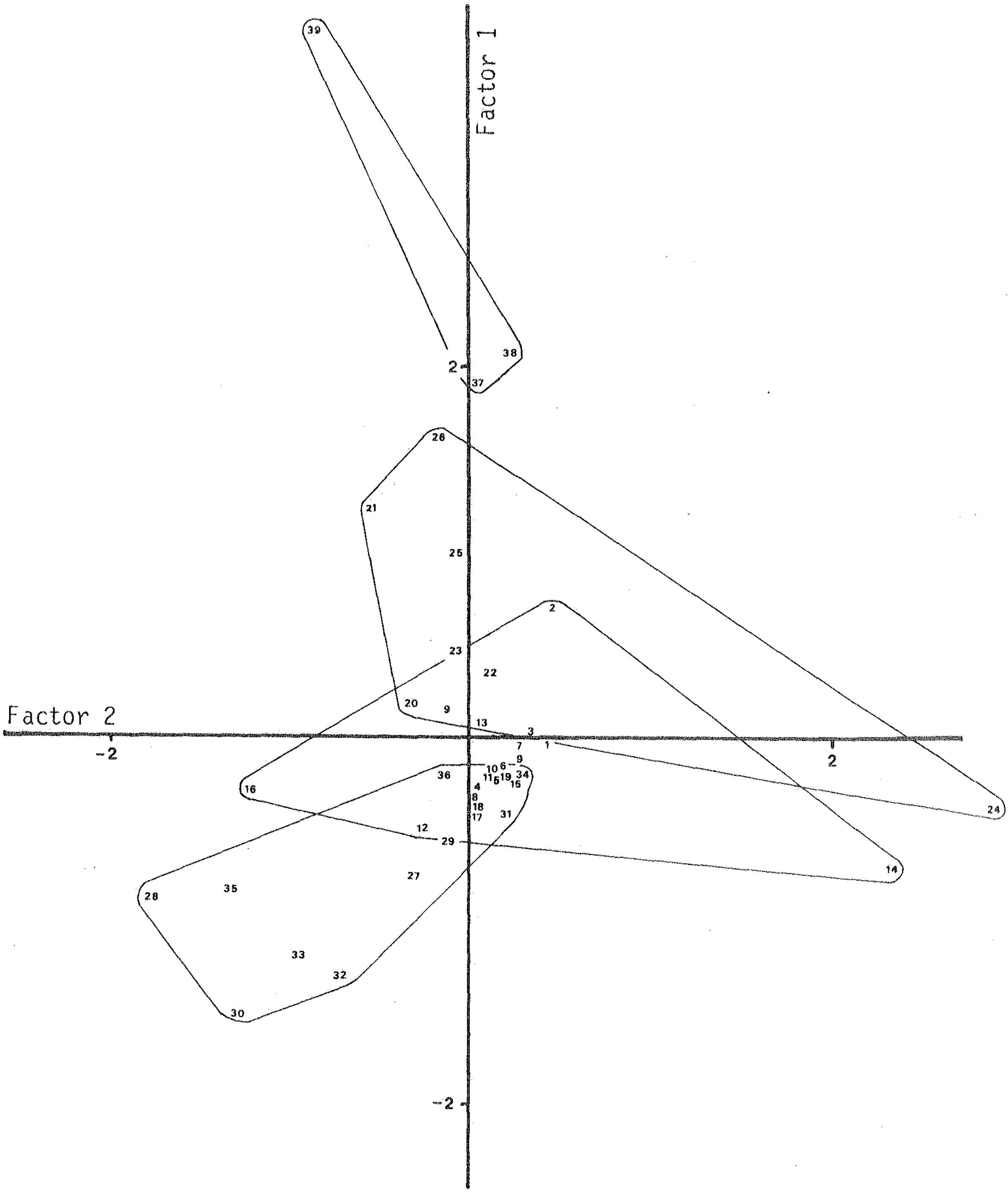


Fig. 4:25. Fish species plotted by factor scores on Factors 1 and 2 of rotated Q-mode binary discriminant analysis based on their salinity characteristics. Species are coded and assembled according to Table 4:24.

conditions. Several of the most highly correlated species, *Syngnathus tuckeri, Ammotretis liturata* and *Crapatalus arenarius* are probably steno-haline and rarely occur in estuarine habitats (see Section 4:4:2). In contrast, high negative correlations were associated with dominant estuarine species, *Retropinna tasmanica, Atherinosoma microstoma, Pseudaphritis urvillii, Favonigobius tamarensis, Pseudogobius olorum* and *Tasmanogobius* sp. 3,that possessed preferences for brackish water, although all were collected from freshwater. *Anguilla australis*, a catadromous species (McDowall and Beumer, 1980),has a partial preference for brackish waters.

The second rotated factor accounted for a further 14% of the variance in the standard residuals matrix. Factor scores distinguished species that preferred polyhaline/euhaline conditions from those that have a liking for oligohaline conditions. The polyhaline/euhaline species (those with high positive factor loadings) were euryhaline marine species that frequently ventured into estuaries but rarely into freshwater. Three species, *Torquigener glaber, Rhombosolea tapirina* and *Stigmatopora nigra,* had loadings exceeding 0.95. Four others, *Atherinason* sp., *Atherinosoma presbyteroides, Gymnapistes marmoratus* and *Arripis trutta,* were only slightly more correlated with this factor than with the first, indicating a slight preference for marine environments. High negative factor loadings characterised the freshwater species, *Prototroctes maraena, Galaxias maculatus* and *G. truttaceus*.

No species were most highly correlated with the third rotated factor which only accounted for 3% of the variance.

A plot of scores of the first two factors from the Q-mode analysis (Fig. 4:25) provided overlapping clusters of the 4 groups identified

Table 4:25. Salinity types of fishes taken during the sampling programme.

Salinity Type	Proportion of species (%)
Stenohaline marine	28.8
Euryhaline I	29.6
Hypereuryhaline I	0.8
Euryhaline II	13.6
Hypereuryhaline II	0.8
Euryhaline III	22.4
Hypereuryhaline III	1.6
Euryhaline V	0.8
Stenohaline freshwater	1.6
Number of species	125

from R-mode analysis. The first factor provided the best separation of groups; freshwater and some estuarine components scored high positive values when the marine components had low positive of negative values.

The second factor served to isolate two hypersaline species, *Atherinosoma microstoma* and *Neoodax balteatus*, which were segregated in the southeastern quadrat.

Comments

The salinity types of the 125 species sampled during this study are summarised in Table 4:25. Only 29% of marine species appeared to be stenohaline and several of these may have been shown to be euryhaline if more samples were taken.

Most marine species exhibited some euryhalinity, although the relatively low proportion of euryhaline II species to euryhaline I and III species suggested that two distinct salinity tolerance groups were present in estuaries. The most extreme group is a well-defined assemblage of widespread marine fishes and diadromous species which can tolerate both marine and freshwater conditions.

Few freshwater fishes enter estuaries and these species are mostly stenohaline. This argument is supported by the total absence of euryhaline IV fishes.

Low numbers of hypersaline species were possibly attributed to the limited data available from hypersaline habitats. *Atherinosoma microstoma* was clearly the dominant species in these habitats. This finding supports work by Chessman and Williams (1974) who sampled it from Victorian ponds ranging in salinity from 29.2 - 84.2^{o}/oo. Lui (1969) determined LD_{50} values for this species ranging from 3.3 - 108^{o}/oo and noted that salinity tolerance was independent of acclimation. Occasional records of this species from freshwater in the upper area of estuaries, could be related to random movements within the estuary rather than to a behavioural pattern of migration. Observations (unpublished data) made on captive specimens, however, indicate that *Atherinosoma microstoma* can survive for several days in freshwater aquaria.

In the absence of detailed salinity tolerance studies, our knowledge of most species is reliant on field records of the nature discussed here. More systematic data and experimental work is required to fully appreciate responses to different salinitylevels of even the most common species.

4:5:2 Substrate Effects

Methods

Occurrence data for species were categorised into 5 substrate types listed below (see also Section 4:2:2). Non-vegetated sites were grouped into either (1) pebbly or (2) sandy and muddy bottoms. Vegetated sites were allocated into groups where (3) freshwater/brackish plants or (4) seagrasses were dominant, or (5) where the only vegetation present was algae. Seagrasses were represented by *Zostera muelleri, Heterozostera tasmanica, Amphibolis antarctica, Halophila ovalis* and *Posidonia australis; Ruppia maritima* and other brackish plants fitted into category 3.

The frequencies of occurrence of species in each substrate category were calculated (Appendix 4:10). Of these, 47 had G-statistics exceeding the 0.05 level of significance (where degrees of freedom = 4, G-statistic = 9.49).

Results and Discussion

Q-mode analysis

The first factor, which accounted for 51% of the variance of the data matrix, contrasted seagrass habitats with the other variables (Table 4:26). 'Sand/mud' and habitats dominated by algae had the highest positive factor loadings. Hence, species positioned in the bottom quadrants of a plot of scores on the first 2 factors (see Fig. 4:26) either displayed a marked affinity for seagrass habitats or a dislike for one or more of the other habitats. These species included *Stigmatopora argus, Stigmatopora nigra, Atherinosoma presbyteroides, Gymnapistes marmoratus, Nesogobius* sp. 2, *Heteroclinus perspicillatus, Neoodax balteatus, Acanthaluteres spilomelanurus* and *Meuschenia freycineti*.

Table 4:26. Factor loadings from Q-mode binary discriminant analysis of the substrate characteristics of habitats.

Substrate type	Factor 1	2	3	4
Pebbles	.437	.535	-.699	.187
Sand/mud	.775	-.558	-.201	-.218
Freshwater/brackish plants	.475	.741	.301	-.366
Seagrasses	-.972	.216	.027	.083
Algae only	.778	.073	.442	.440
Variance proportions	.514	.239	.164	.083

The second factor accounted for 24% of the variance and contrasted negatively correlated sand/mud habitats with the other variables which were loaded positively. Of these, 'freshwater/brackish plants' were most highly correlated. Species apparently associated with sand/mud habitats were represented in the western quadrats of Fig. 4:26. *Ammotretis rostratus*, *Ammotretis liturata*, *Rhombosolea tapirina*, *Crapatalus arenarius*, *Aldrichetta forsteri* and *Arripis trutta* were extreme examples.

'Pebbly substrates' were most highly loaded on factor 3. High negative factor scores for *Geotria australis* and *Anguilla reinhardtii* probably related to this variable.

The fourth factor accounted for the final 8% of the variance in the data matrix. As none of the variables was highly correlated with this factor habitat trends were unimportant.

R-mode analysis

The first rotated factor identified 37 of the 47 species and occupied 75% of the variance of the standard residuals matrix (Table 4:27).

Table 4:27. Factor loadings, variance proportions, and factor scores for rotated factors based on substrate characteristics.

Code No.	Species	Factor 1	2	3	4
1	*Stigmatopora nigra*	.998	.022	.051	.041
2	*Atherinason esox*	.997	.001	.053	.053
3	*Girella tricuspidata*	.997	-.009	.054	.052
4	*Nesogobius sp.5*	.997	.018	.054	.054
5	*Neoodax balteatus*	.996	.035	.053	.056
6	*Heteroclinus perspicillatus*	.996	.035	.053	.057
7	*Penicipelta vittiger*	.996	.043	.053	.057
8	*Syngnathus phillipi*	.996	.043	.053	.058
9	*Neoodax semifasciata*	.996	.042	.054	.058
10	*Brachaluteres jacksonianus*	.996	.043	.055	.058
11	*Nesogobius sp.7*	.996	.043	.055	.058
12	*Engraulis australis*	.996	.044	.053	.059
13	*Meuschenia freycineti*	.995	.079	.051	.044
14	*Caranx georgianus*	.994	-.091	.052	.040
15	*Diodon nicthemerus*	.993	-.101	.053	.040
16	*Gymnapistes marmoratus*	.992	.118	.045	.012
17	*Acanthaluteres spilomelanurus*	.991	.119	.047	.025
18	*Spratelloides robustus*	.991	-.118	.053	.038
19	*Hyporhamphus melanochir*	.990	-.130	.045	-.009
20	*Cristiceps australis*	.990	.131	.047	.024
21	*Favonigobius tamarensis*	.989	.143	.010	.022
22	*Torquigener glaber*	.987	-.145	.043	.060
23	*Atherinason sp.*	.986	.151	.033	-.068
24	*Stigmatopora argus*	.985	.149	.043	.080
25	*Nesogobius sp.2*	.972	-.216	.035	-.087
26	*Atherinosoma presbyteroides*	.959	-.259	.024	-.108
27	*Atherinosoma microstoma*	.959	.147	.003	.241
28	*Pseudolabrus tetricus*	.953	.299	.032	-.046
29	*Favonigobius lateralis*	.934	-.353	.048	.005
30	*Leptonotus semistriatus*	.888	.447	.019	-.107
31	*Platycephalus bassensis*	.824	-.560	.033	-.079
32	*Pseudogobius olorum*	.799	.523	-.013	.295

Table 4:27 (cont.).

Code No.	Species	Factor 1	2	3	4
33	*Pseudaphritis urvillii*	.754	.455	.288	.376
34	*Aldrichetta forsteri*	.712	-.497	-.058	-.493
35	*Anguilla australis*	.633	.372	.574	.362
36	*Crapatalus arenarius*	-.877	.145	-.109	-.446
37	*Ammotretis liturata*	-.862	.222	-.108	-.444
38	*Syngnathus tuckeri*	.381	.861	-.045	-.333
39	*Ammotretis rostratus*	-.182	-.882	-.091	-.425
40	*Rhombosolea tapirina*	.596	-.779	-.010	-.196
41	*Geotria australis*	-.039	-.024	.996	-.077
42	*Anguilla reinhardtii*	-.076	.030	.989	.122
43	*Galaxias truttaceus*	.401	-.048	.914	.026
44	*Nannoperca australis*	-.281	.183	-.061	.940
45	*Urocampus carinirostris*	.688	.060	.003	.723
46	*Galaxias maculatus*	-.396	.382	.561	.619
47	*Arripis trutta*	-.506	.052	-.167	-.844
Variance proportions		.752	.122	.071	.055
		Factor Scores			
Pebbles		-.060	-.076	1.779	-.162
Sand/mud		-.973	-1.306	-.580	-.460
Freshwater/brackish plants		-.268	.338	-.289	1.712
Seagrasses		1.683	-.381	-.428	-.201
Algae only		-.382	1.425	-.482	-.890

Thirty-five species correlated positively with this factor and 27 of these had loadings greater than 0.95. Such high correlations indicate that these species have a strong affinity for seagrass habitats and a dislike for unvegetated sandy and muddy habitats. Conversely, negatively correlated species, *Crapatalus arenarius* and *Ammotretis liturata,* exhibited a preference for 'sand/mud' habitats and avoided seagrass habitats.

The second rotated factor, which accounted for approximately 12% of the variance, identified three species: *Syngnathus tuckeri, Ammotretis rostratus* and *Rhombosolea tapirina*. The factor scores indicated that 'sand/mud' was contrasted with algal habitats. *S. tuckeri*, which preferred algal habitats and avoided sand/mud habitats, was commonly found on semi-exposed and exposed beaches (see Section 4:4:4) where vegetation, when present, was usually detached. Because unvegetated beaches are generally sandy, the presence of detached algae is possibly obligatory to the occurrence of some species in these habitats. *Ammotretis rostratus* and *Rhombosolea tapirina* were negatively correlated with this factor and thus exhibited a preference for sand/mud habitats.

In essence, factors 1 and 2 both served to identify species that had affinities for sand/mud habitats based on their relative avoidances of algal and seagrass habitats. *Crapatalus arenarius* and *Ammotretis liturata* exhibited a dislike for seagrass habitats but showed some affinity for algal habitats. *Rhombosolea tapirina* avoided algal habitats but exhibited a moderate association with seagrass habitats.

The third and fourth rotated factors accounted for the final 13% of the variance in the data matrix; 7 species were identified. *Geotria australis, Anguilla reinhardtii* and *Galaxias truttaceus* had high positive correlations on the third factor. Factor scores clearly demonstrated a contrast between pebbly beaches and other habitats. All pebbly beach samples were taken upstream of the riffle zones, hence the fauna was typically

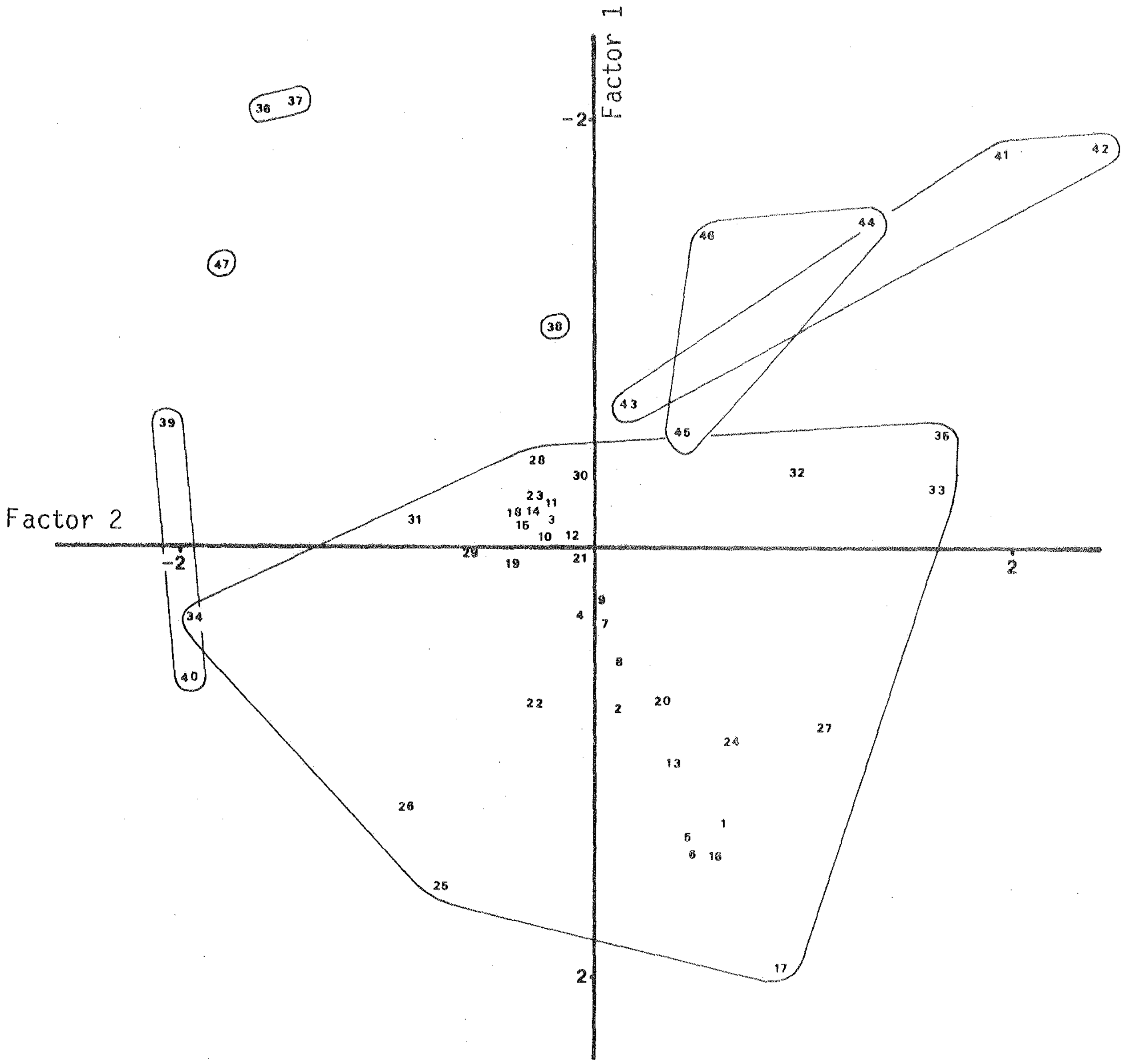


Fig. 4:26 Fish species plotted by factor scores on Factors 1 and 2 of Q-mode binary discriminant analysis based on their substrate characteristics. Species are coded and assembled according to Table 4:27.

freshwater. *Nannoperca australis, Urocampus carinirostris* and *Galaxias maculatus* were correlated most highly and positively with the fourth factor which identified freshwater/brackish plant habitats. Algal habitats possessed a high negative score and served to identify *Arripis trutta.* Unlike *Syngnathus tuckeri,* this species was not highly loaded positively on factor 2 because it occurred commonly in sand/mud habitats. Moderate negative loadings on the first factor supported this assumption.

The R-mode groups were isolated on a plot of Q-mode rotated factor scores (Fig. 4:26). The first factor primarily discriminated between the 'seagrass' and some 'sand/mud' species, whereas the second segregated 'sand/mud' species from 'algal' and 'pebbly bottom' species.

Comments

Substrate, an important factor in characterising estuarine faunas (Day, 1951; Day and Grindley, 1981), is important in determining the distributions of the Australian estuarine fishes (Hoese, 1978; Lenanton, 1977). The associations isolated by the B.D.A. analysis show that some species have significant preferences and dislikes for particular substrate types. Clearly, substrates have a controlling influence on the occurrences of fishes in parts of the Tasmanian shore zone. It was impossible to ascertain whether this influence was exerted directly by characteristics on the substrate or by other co-occurring physical parameters. Similarly, the origins of a particular substrate type could be totally dependent on another environmental variable. For example, turbidity is important in determining sediment type and controlling the distribution of macrophytes (Cooper and Milne, 1938). Some seagrasses may only develop in areas with suitable sediment types. Consequently the presence of seagrass preferring species in these areas may be indirectly dependent on turbidity.

Sheperd and Sprigg (1976) have outlined different seagrass communities in Gulf St. Vincent, South Australia, which appeared to have distinct invertebrate components. Preference trends of fish species for particular seagrass types were not examined in this study but cannot be discounted. Bass Strait is the southern most distributional limit of *Posidonia* and some species, such as *Siphonognathus argyrophanes*, *Leptoichthys fistularis* and *Cristiceps argyropleura*, which live amongst this seagrass type, have coincidental ranges in this region.

4:5:3 Tidal Effects

Method

Tidal status (whether wholly intertidal or partly subtidal) was recorded at each sample (see Section 4:2:2). Sites with indeterminable status were classed as subtidal. Proportional occurrences for species were calculated for both intertidal and subtidal samples based on the total numbers of sample from each group. Intertidal species were then ranked acccording to their relative occurrences in 145 intertidal samples.

Results and Discussion

Fifty-three species (42%) collected during the sampling programme occurred in intertidal samples (Table 4:28). These were represented by nektonic and benthic components and other incidental species living in association with algal drift. Both nektonic and benthic groups had species that actively migrated into the intertidal zones plus others that occurred only incidentally.

Subtidal seine samples, apart from those taken at extreme low water, swept at least some part of the intertidal zone. Species that possessed

Table 4:28. Relative occurrence of species in intertidal and subtidal samples expressed as a percentage occurring in each tidal area.

Rank	Species	Proportional Occurrence Intertidal	Proportional Occurrence Subtidal	Total Occurrence
1	*Aldrichetta forsteri*	62.8	51.5	425
2	*Rhombosolea tapirina*	46.2	45.5	362
3	*Atherinosoma presbyteroides*	35.2	38.3	299
4	*Nesogobius sp.2*	32.4	37.7	291
5	*Arripis trutta*	31.7	32.4	256
6	*Atherinosoma microstoma*	26.2	35.0	265
7	*Ammotretis rostratus*	25.5	37.0	277
8	*Galaxias maculatus*	10.3	16.5	122
9	*Torquigener glaber*	7.6	14.2	103
10	*Atherinason esox*	6.9	5.1	43
11	*Gymnapistes marmoratus*	6.2	13.7	98
	Crapatalus arenarius	6.2	8.2	62
13	*Favonigobius tamarensis*	5.5	14.0	99
	Contusus richei	5.5	4.3	36
15	*Ammotretis liturata*	4.8	6.3	48
	Pseudaphritis urvillii	4.8	16.1	111
	Favonigobius lateralis	4.8	4.9	39
	Contusus sp.	4.8	3.6	30
19	*Hyporhamphus melanochir*	3.5	5.3	39
20	*Prototroctes maraena*	2.8	.7	9
	Retropinna tasmanica	2.8	6.0	43
22	*Pseudogobius olorum*	2.7	7.6	53
	Tasmanogobius lordi	2.7	2.9	23
24	*Spratelloides robustus*	2.1	1.9	15
	Lovettia sealii	2.1	2.5	19
	Galaxias truttaceus	2.1	4.3	31
	Anguilla australis	2.1	4.8	34
	Myxus elongatus	2.1	2.3	18
	Platycephalus bassensis	2.1	8.2	56
30	*Stigmatopora argus*	1.4	9.1	61
	Atherinason sp.	1.4	3.2	23
	Amoya bifrenatus	1.4	1.4	11
	Tasmanogobius sp.3	1.4	6.2	42

Table 4:28 (cont.).

Rank	Species	Proportional occurrence Intertidal	Subtidal	Total Occurrence
34	*Acanthaluteres spilomelanurus*	1.4	17.8	117
	Meuschenia freycineti	1.4	7.6	51
36	*Engraulis australis*	0.7	1.5	11
	Syngnathus tuckeri	0.7	1.9	13
	Syngnathus curtirostris	0.7	0.3	3
	Syngnathus phillipi	0.7	4.0	27
	Urocampus carinirostris	0.7	2.2	15
	Atherinason hepsetoides	0.7	1.1	8
	Platycephalus castelnaui	0.7	1.1	8
	Genypterus sp.	0.7	0.2	2
	Trachurus declivis	0.7	0.3	3
	Caranx georgianus	0.7	2.5	17
	Girella tricuspidata	0.7	1.7	12
	Crapatalus sp.	0.7	3.9	26
	Nesogobius hinsbyi	0.7	6.3	42
	Nesogobius sp.7	0.7	0.9	7
	Heteroclinus perspicillatus	0.7	10.3	68
	Pseudolabrus tetricus	0.7	1.1	8
	Neoodax semifasciata	0.7	2.6	18
	Neoodax balteatus	0.7	9.7	64

preferences for intertidal environments would be expected to exhibit relatively high occurrences in subtidal samples. Similarly, species with low ratios of intertidal to subtidal occurrences would rarely be major intertidal migrants. Both assumptions are true providing that the proportion of subtidal and intertidal samples for each habitat are approximately equal. With the exception of a small bias for data from closed systems, which were not tidal, these conditions were approximated here.

The 7 ubiquitous species, *Aldrichetta forsteri, Rhombosolea tapirina, Atherinosoma presbyteroides, A. microstoma, Nesogobius* sp. 2, *Arripis trutta* and *Ammotretis rostratus,* were the most frequently occurring species in the intertidal areas. Likewise, their subtidal occurrences were amongst the highest. Less abundant species that frequently migrated into intertidal areas included *Prototroctes maraena, Spratelloides robustus, Torquigener glaber, Contusus richei, Contusus* sp. and *Atherinason esox.*

The nektonic or benthopelagic migrants were mostly active schooling species. It is not known whether these fishes migrated with the tides or moved randomly in and out of the area between ebbs. *Aldrichetta forsteri* was the dominant species, although *Atherinosoma presbyteroides, A. microstoma, Arripis trutta* and *Galaxias maculatus* also occurred frequently.

Some benthic species, particularly flounders (Pleuronectidae) and gobies (Gobiidae), were common among the intertidal migrants. Juvenile *Rhombosolea tapirina* and *Ammotretis rostratus* were observed moving onto intertidal flats on the ebb tide. Eleftheriou (1979) recorded similar migrations in other flatfish species and Gibson (1973) associated such migrations with the maintenance of a depth preference. Gibson categorized tidal migrant species into those which migrated up and down the whole intertidal zone, those which only reach the mid-tidal level, and those which only just penetrate the intertidal zone.

Migration through the whole length of the intertidal area could be difficult for some species. Mobile nektonic species might be expected to cover large distances in the duration of one tidal cycle, but for smaller, low activity benthic species, these migrations would need to be directed parallel to the tidal flow. *Rhombosolea tapirina, Ammotretis rostratus* and *Nesogobius* sp. 2 were collected near high tide marks on some beaches in Bass Strait where the width of the intertidal zone can exceed 1 km. Unassisted daily migrations of this magnitude could prove to be a considerable energy drain on poor swimmers such as gobies, however, this drain could be considerably reduced by coinciding activity and tidal flow patterns. An activity peak, which may be related to tidal rhythm, has been detected in *Nesogobius* sp. 2 (Robertson, 1981).

Several species were moderately common in subtidal samples but were rarely found intertidally. These species, *Syngnathus tuckeri, Stigmatopora argus, Syngnathus curtirostris, Syngnathus phillipi, Urocampus carinirostris, Heteroclinus perspicillatus, Neoodax semifasciatus, Neoodax balteatus, Acanthaluteres spilomelanurus* and *Meuschenia freycineti,* belonged to 3 families (Syngnathidae, Monacanthidae and Odacidae) whose members possessed affinities for vegetated habitats (see Section 4:5:2). Their occurrence in intertidal zones could be associated with a presence of detached seagrasses and algae transported intertidally by wind and currents. The incidence of these species in samples was highest after storms and windy periods.

4:6 DISCUSSION AND CONCLUSIONS

The shore zone of Tasmania and its nearby islands contains a diverse assembly of geomorphological types. Factors, such as climate, wave exposur runoff and tides, affecting the environmental conditions of habitats within these types, are equally complex and variable.

Marine environments of the nearshore regime exhibit variability in substrate type and profile that is determined largely through an interactio between exposure to waves and tides. As substrates and the extent of development of macrophytic vegetation are of prime importance in determining the occurrence of marine animals (Moore, 1958), an understanding of the basic physical characteristics of these habitats is an important prelude to ecological studies of their faunas.

Environments of the Tasmanian estuarine regime show geomorphological and hydrological variations that are mainly affected by geological, tidal and climatic characteristics. The geological history of the area mainly influences the depth and form of an estuary. Larger southern Tasmanian estuaries enter ria coasts and their form is markedly different from northern and eastern Tasmanian rivers which flow through coastal plains. Tidal level differences afford differing levels of scour and tideflat development while precipitation and runoff control the salinity characteristics of these systems. In the West where rainfall is high, estuarine systems are predominantly freshwater or oligohaline, whereas those in the East are mostly polyhaline or marine. Similarly, the extent and continuity of adjacent marginal zones is closely correlated with runoff patterns. A combination of low tidal range and runoff and high exposure to wave energy is instrumental in causing the closed lagoon formations in the North-East and Flinders Island. Once again, the productivity of macrophytes and their associated faunas is dependent on a balance between these environmental parameters.

A management oriented classification of the sedimentary environments of the estuarine regime and shore zone, based only on main coastal types such as beach, estuary, lagoon and coastal lake, is not totally suitable because of the subtle regional variability present within each type. Similarly, a regional classification of the form proposed by Jennings and Mabbutt (1977) for Tasmanian physiographic regions is also inappropriate as some areas of the coastline are dominated by one type of system while others are a combination of several types. Lagoon and coastal lakes of the eastern Furneaux Group and the low salinity tidal and beach-dammed rivers of the West Coast are clearly diagnostic of their respective areas. However, the complexity and diversity of habitat types is much greater in the South-East, where almost all coastal types represented around Tasmania can be found.

Although simplified, the classification proposed herein is, in the absence of more detailed studies, a useful guide to the habitat types occurring in this region. Regional investigation of related coastal types, such as a study by McLay (1976) on tidal inlets of New Zealand, will be required to complete this classification, thus providing a better understanding of the physical conditions affecting animal communities living in these environments.

The term 'community' has been used in two main senses by zoologists (Krebs, 1978). In a broad sense, the community represents 'any assemblage of populations of living organisms in a prescribed area or habitat'. In comparison, a community type, which defines a biotope, should have a relatively constant composition and must be recognisable by its components. Hence, an ideal biotope, which could be applied meaningfully in coastal management studies, should consist of populations of species that occur only at a single habitat type. In reality, most biotopes are not 'ideal' but are represented by species which are not restricted to one biotope (Krebs, 1978). Thus the diagnostic feature of a biotope is more related to the overall composition of the resident assemblage than to any unique compositional characteristics.

The application of the concept of abiotic boundaries for communities is more complicated in aquatic than in terrestrial environments where it has mostly been used (Stephenson, 1973). Hesse *et al* (1937) chose to provide a hierarchical classification for habitats in a similar manner to biological taxa with biotopes on a level with species. Such categories are suggestive of well-defined boundaries but, in fact, ecological assemblag are often complex and range from loosely integrated aggregations to highly stable co-adapted groups (Mills, 1969). For highly stable groups in equilibrium with the environment for long periods the biocoenotic view is realistic, however, this concept becomes less realistic when the component species are independently distributed along a continuum of habitats. Stephenson (1973) has discussed these concepts at length and he concluded that most marine communities are difficult to delineate by biotic criteria.

Krebs (1978) has stated that when communities, like species, form discrete entities then a taxonomy of communities can be constructed. However, when communities are not discrete they can still be classified according to an unnatural system which could be merely convenient rather than truly representative of nature's true structure. This argument, whilst certainly true for extreme cases, is not applicable for some intermediate situations. Communities based on a group of high fidelity dominant species and a number of less common transient species could still form a 'natural' grouping of closely associated species.

Fish species inhabiting sedimentary habitats of the shore zone and estuarine regime of Tasmania can be regarded as consisting of widespread abundance dominants and assemblages of less abundant species, some of which exhibit affinities for particular habitat types. It should be noted that these widespread species are ubiquitous to sedimentary environments and are rarely found in rocky habitats (Edgar, 1981; Last, unpublished data). Based on either occurrence or abundance information, these ubiquitous or widespread species would receive priority in the selection of 'indicator' species for all the soft-bottom habitats discussed. Clearly, the occurrence of these species alone is not indicative of a single biotope but instead typifies a fish assemblage of the whole coastal sedimentary environment. The abundances and frequencies of occurrence of these species, however, did show subtle variations in habitat selection which are probably indicative of infrastructural preferences.

The associations of less abundant and less frequently occurring species contain a mixture of migrant species and high fidelity residents. Migrants consist of species characteristic of fish communities found outside sedimentary environments of the shore zone, such as those normally found in offshore demersal, coastal, pelagic, rocky reef and freshwater habitats. These species, although forming a considerable proportion of the fauna, are low in abundance and do not typify any community type found in this environment. Conversely, high fidelity species, which are often abundant within their distributions, are probably most useful in delimiting communities.

Problems faced in determining community types can be analogous to those sometimes facing taxonomists when classifying animals at supra-specific levels. Assemblages of high fidelity species characterise various biotopes while the widespread species represent the collection of biotopes which make up sedimentary environments of the shore zone. However, due to the presence of peripheral associations and varying levels of fidelity, these categories are rarely distinct. Proposals to recognise marine communities as associations or 'proximity groupings' (Mills, 1969; Stephenson, Williams and Cook, 1972; Stephenson, 1973) were supported in this study of fish assemblages. This broader meaning of community is implied when the term is used in following sections.

The inherent variability in physical, chemical and biological characteristics of Tasmanian coastal habitats suggests that a biotopic approach to coastal fish communities may not be totally satisfactory. Firstly, the major habitat types which were classified largely on geomorphological and physical criteria did not represent distinct biotopes. As most coastal classifications have been constructed using similar criteria, the dangers of extrapolating their usefulness into biologically related aspects of coastal management are obvious. Secondly, the boundaries between adjacent habitats were sometimes difficult to delimit. Major habitat types were mostly distinguishable but, on occasions, did overlap. In addition, as outlined earlier in this discussion, regional variability within types, complicated this classification. Substrate type, tidal state and the salinity characteristics of the habitat can each have an effect on faunal components.

Some fish species showed an affinity for seagrass habitats, and their distribution in each major habitat is dependent on the presence of vegetation. Similar relationships are evident between salinity regimes and the occurrence of species (Section 4:5:1). In the presence of such extreme microhabitat variability, the usefulness of biotopes, in predicting faunal composition, is questionable. However, the major faunal elements comprising biotopes of the shore zone can be isolated and are predictable if physical information such as substrate type, salinity and degree of exposure for the sampling area are known.

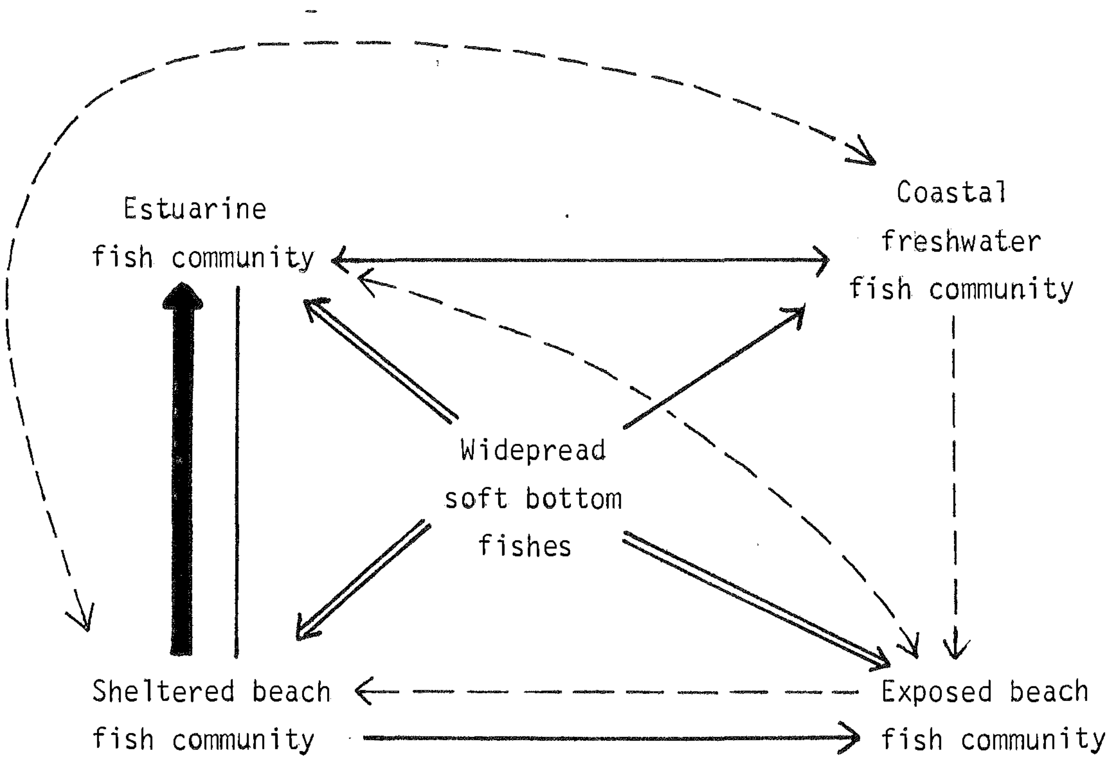


Fig. 4:27. Diurnal fish assemblages of sedimentary habitats of the Tasmanian shore zone. The thickness of arrows reflects the degree of overlap between adjacent assemblage types in each habitat; dotted lines indicate only minor overlap.

The general features of the fish assemblage found in these habitats based on available data is summarised in Figure 4:27.

The generality of these associations is difficult to assess in the absence of comparable studies. Wenner *et al.*, (1982) examined fish and decapod crustacea fauna of an estuary in South Carolina, U.S.A. They distinguished 4 associations which consisted of assemblages of euryhaline, coastal marine and stenohaline/freshwater anadromous species and a category of species that tolerated a range of intermediate to low salinities. These categories were stated to be rather artificial as some species may have established peripheral associations with those outside their group. A widespread penetration of the estuarine environments was used as an an example. Their observations do reinforce inadequacies,also detected in the present study, in categorising assemblages of highly mobile and often environmentally tolerant species, such as fishes, into biocenoeses. They did not, however, examine interactions between the fidelity of species and the main physical parameters.

Other factors, such as ontogenetic and temporal variability in the occurrence of species, are important in delimiting communities. Highest fidelity species are usually permanent residents but there are exceptions. Juvenile *Arripis trutta* form an important component in the shore zone fish fauna whereas adult fishes are not common in this environment. Adults generally occur in schools beyond the nearshore zone and spawn outside the Tasmanian region (Stanley, 1980). Hence, many assemblages, such as those living in estuaries, where habitat preferences of species vary with age (Wallace and Van der Elst, 1975), consist partly of an aggregation of life history stages not only of Linnaean species. Emery (1973) and Helfman (1978) have regarded these forms as separate 'ecological species'.

Some fish communities have exhibited distinct diel changes in abundance and occurrence of their major species (e.g. Roessler, 1965; Hoese *et al.*, 1968; Grimes, 1975; van den Broek, 1979). In this study of shore zone fishes, only the diurnal characteristics of the fauna were examined. Robertson (1980), studying a shallow water eelgrass fish community in Victoria, found that most of the major species in his study area exhibited diel patterns of activity. Consequently it is possible that nocturnal changes in composition, particularly in habitats adjacent to reefs or close to deep bays, may occur. Temporal changes in community structure are examined in more detail in the following chapters.

CHAPTER 5

ASPECTS OF THE ECOLOGY OF FISHES OF A SANDFLAT IN THE DERWENT ESTUARY

5:1 INTRODUCTION

Knowledge of day-night usage of various habitats by fish is poor (McCleave and Fried, 1975) while conclusions on activity patterns have been drawn largely from examination of stomach contents (Hobson, 1965). Current studies indicate that these usage patterns may be complex. Some authors have shown that numbers of individuals (i.e. Roessler, 1965; Grimes, 1975; van den Broek, 1979) and number of species (i.e. Roessler, 1965; Hoese *et al.*, 1968; Dybdahl, 1979) are greater at night than day. This 'night factor', however, was not detected in other studies. Huddart (1971) found no appreciable diel differences in abundances of fish in the Thames estuary (U.K.). A study of shore zone fishes in Maine (U.S.A.) (McCleave and Fried, 1975) yielded similar results for numbers of species but fewer individuals were collected at night. Horn (1979), examining shallow-water fishes of Morro Bay, California, found larger numbers of individuals and greater biomass at night but nearly equal numbers of species were caught during day and night samples.

Published information on diel compositions of Australian inshore fishes appears to be restricted to brief studies by Lenanton (1977), Stephenson and Dredge (1976), Dybdahl (1979) and Robertson (1980) In addition, most community studies on Australian soft-bottom marine fish relate to seagrass faunas and only Stephenson and Dredge (1976) and Quinn (1980) provide comprehensive seasonal information on abundance, diversity and species composition of fishes living over sandflats or mudflats in estuaries.

The aims of the following study were twofold: to investigate possible diel and seasonal differences in the number, sizes and species composition of fishes inhabiting a temperate sandflat environment and to provide information on the nature of the populations and the ecological roles of the species.

5:2 STUDY AREA

Nutgrove Beach is a small sandflat, on the western shore, in the estuary of the Derwent River (147° 21'E, 42° 54'S). The sampling area (Fig. 5:1), approximately 100 m long and in the northern sector, is protected from direct southeasterly swells by a small cuspate foreland and receives only low energy wave action during northerly weather.

The hyrology of the Derwent Estuary has been studied by Guiler (1955) and Rochford (1951), and a 14 month survey was completed by the Tasmanian Fisheries Development Authority in 1977 (unpublished data). The inapplicability of the classical estuarine classification of Pritchard (1955) to many Australian estuaries has been discussed by Perkins (1974) and the area is possibly best characterised as polyhaline to euhaline.

All forms of netting are prohibited in the area at night and only gill netting is permitted during the day (Tasmania: Sea Fisheries Regulations, 1962). Consequently, fishing pressures in this part of the estuary are low, although some spearing, angling and limited illegal seining does occur.

The sandflat provides an important recreational facility during the

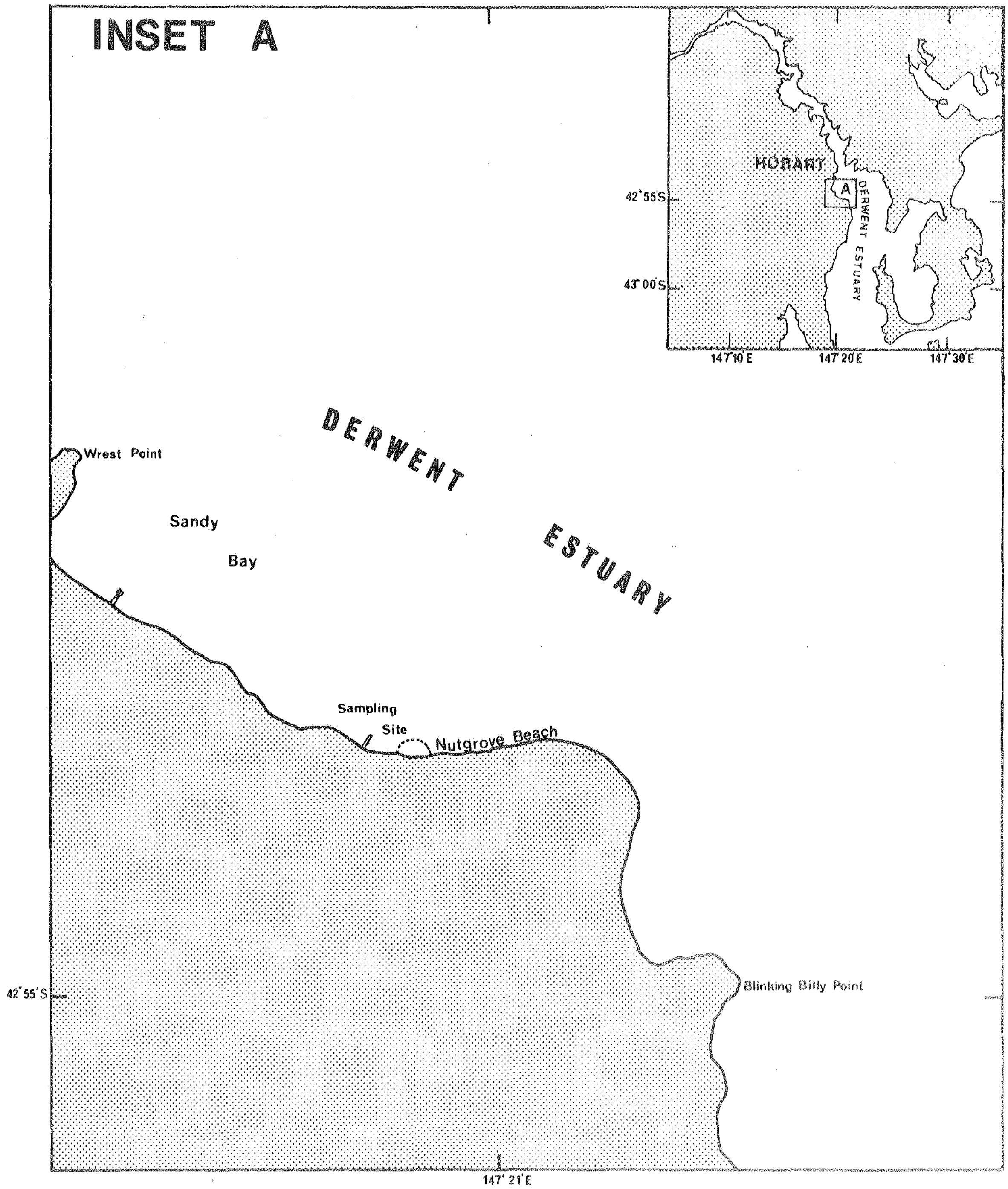


Figure 5:1. Location of study area.

summer months but water quality in the river has deteriorated in recent years. Some effluent is discharged from nearby storm water drains and heavy metal pollution of the sediments is high (Bloom, 1975).

5:3 METHODS

5:3:1 Field Sampling Procedures

Fishes were sampled approximately fortnightly, around midday and midnight, on corresponding ebb tides between November, 1976 and December, 1977.

The beach seine (S1) was set parallel to the shore from a 3 m skiff. The net was hauled manually using two 50 m polypropylene lines over an effective area of about 750 m^2 and maximum depth of 3 m. All specimens were measured (total length, T.L.) and assigned to the appropriate size classes: less than 100 mm, 100-199 mm, 200-299mm, and greater than 300 mm.

A sub-sample of species required for gonad and gut content inspection was taken to the laboratory for further examination; other individuals were temporarily held in buckets before live release. Some small individuals (less than 50 mm T.L.) were difficult to identify at night and were also retained. Gas and battery lamps provided lighting during night sampling and these were isolated from the sampling area prior to beaching the net.

5:3:2 Underwater Observations

Thirty-six hours (equally divided between night and day) were spent underwater using scuba equipment. This provided additional non-quantitative information on bottom characteristics and behavioural and distributional patterns of species.

5:3:3 Physical Data

Temperature was measured 30 cm below the surface and minimum and maximum salinites were determined from salinity profiles. State of sea, transparency, brightness, and wind speed and direction were also recorded concurrently at each sample.

5:3:4 Analytical Procedures

Diversity and abundance patterns were examined using four widely used indices (Allen and Horn, 1975; Dahlberg and Odum, 1970): the Shannon-Weaver function, H' (Margalef, 1957); the species richness index, D (Margalef, 1969); the equitability index, E (Lloyd and Ghelardi, 1964); and the evenness index, J (Pielou, 1966).

Temporal distributions of fishes were examined by step-wise discriminant and canonical analyses using B.M.D. program No. 7M (Dixon, 1970). In summary, the analysis compounds within group variations to obtain maximum separation between groups (Gp); disentangles the correlations between variables (Vb) so that each character brings in only the amount of information that is new to it; selects adjusted variables sequentially (based on F values) that exhibit the maximum discriminatory variation; adjusts variables for relative differences in group means, correlations, and within-group variations, and only those variables exceeding the F value for inclusion contribute to the discriminant functions; selects axes (canonical variates) to give maximum separation between groups; and calculates a set of coefficients based on variation obtained from the original groups but which can be applied to any subsequent group to determine the status of the latter relative to the former. Posterior probabilities and squares of the Mahalanobis distances (D^2; Blackith and Reyment, 1971) are determined for each group member (samples). Samples are classified into the group showing greatest similarity (the lowest D^2 and the highest posterior probability).

Diel and seasonal differences in the numbers of individuals and species were examined using two-way analyses of variance (6 replicates). Data were log transformed for numbers of individuals and root transformed when using numbers of species (Sokal and Rohlf, 1969). The normal method of denoting significance levels (i.e. by asterisk) is used in the resulting ANOVA tables.

5:4 RESULTS AND DISCUSSION

5:4:1 Hydrological Data

Surface temperatures ranged from 8.3 to 22.8^{O}C ($\bar{x}$ = 14.5) at day and 9.5 to 19.2^{O}C ($\bar{x}$ = 13.2) at night (Fig. 5:2).

Salinities near the surface varied from 16.8 to 13.3^{O}/oo ($\bar{x}$ = 27.4) while bottom salinities varied between 21.2 and 34.5^{O}/oo ($\bar{x}$ = 30.5).

5:4:2 Species Composition and Abundance

A total of 7,790 individuals comprising 50 fish species and 38 families were seined during the sampling period. Percentage occurrences and mean abundances of species at day and night are given in Table 5:1.

Mean species numbers on night samples ($\bar{N}_n$) averaged twice ($\bar{N}_n/\bar{N}_d$ = 2.03) that of day samples ($\bar{N}_d$); sample numbers ranged from 2 - 14 and 7 - 21 for day and night respectively (Fig. 5:3a). This 'night factor', which was highly significant (Table 5:2b), extended through all size classes (Fig. 5:3b-e) but was less obvious for the largest fishes. Mean and total numbers of species sampled at both night and day decreased as the sizes of fishes increased (Table 5:2a). There was also a significant added variance

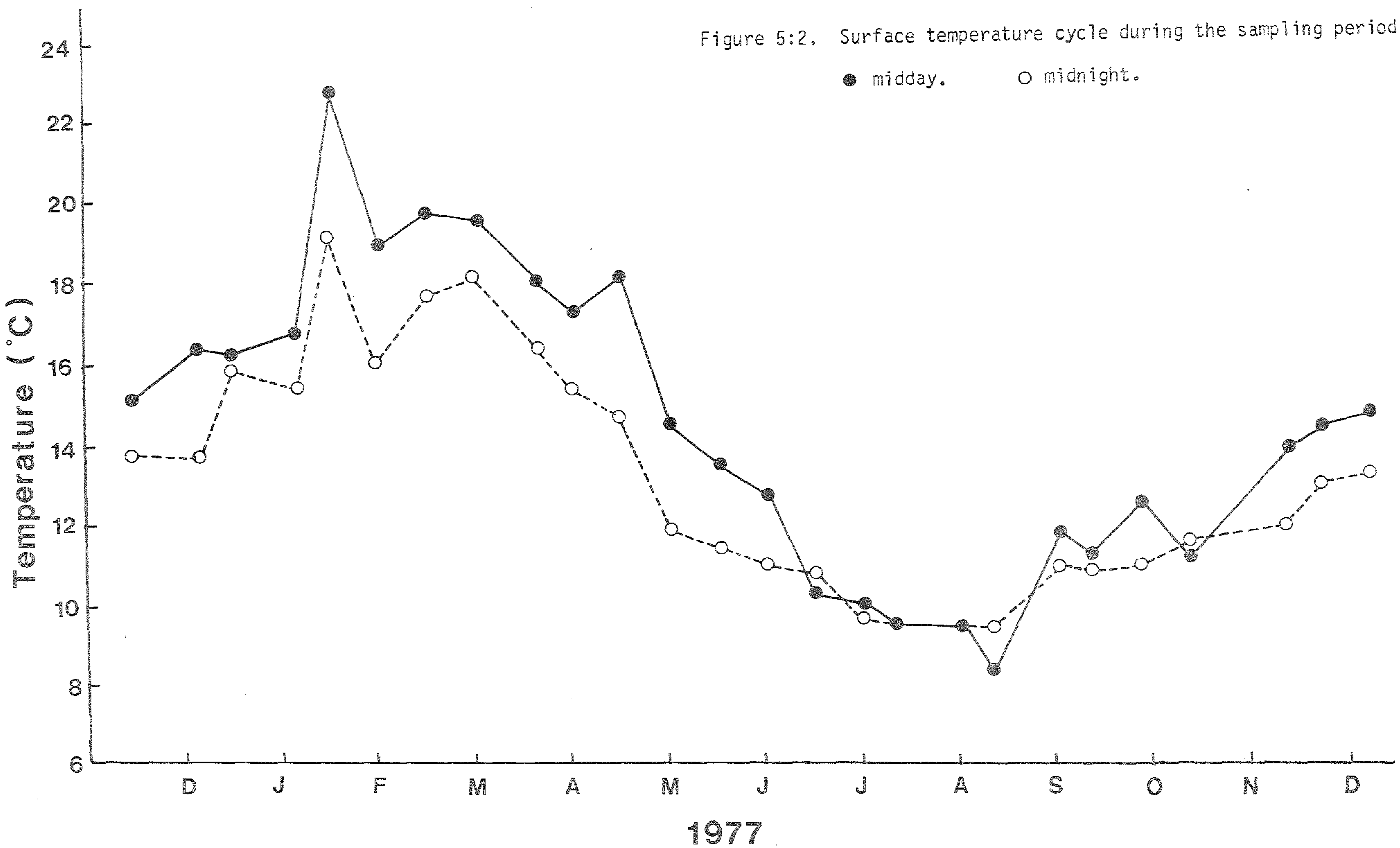


Figure 5:2. Surface temperature cycle during the sampling period.

Table 5:1 Mean abundance ($\bar{x}$), percentage occurrence (f) and spatial (Pos.) and residency (Res) status of species.
B, benthic; BP, benthopelagic; P, pelagic; R, resident; TR, temporary resident; T, transient.

	Day		Night		Status	
	$\bar{x}$D	fD	$\bar{x}$N	fN	Pos.	Res.
Cephaloscyllium laticeps	0	0	0	4	BP	T
Narcine tasmaniensis	0	0	0	4	B	T
Raja whitleyi	0	0	0	4	B	T
Raja lemprieri	0	0	0	4	B	T
Urolophus cruciatus	0.1	8	0.3	23	B	R
Muraenichthys breviceps	0	0	0.1	12	B	R
Galaxias truttaceus	0.3	4	0	0	BP	TR
Lovettia sealii	0	4	0.7	19	BP	TR
Salmo trutta	0	4	0.1	8	BP	T
Brachionichthys hirsutus	0.2	15	0.2	12	B	R
Pseudophycis bachus	0	0	3.2	88	BP	R
Macruronus novaezelandiae	0	0	0.1	4	BP	T
Hyporhamphus melanochir	0.1	4	1.0	31	P	R
Atherinason sp.	0	4	5.2	69	BP	R
Atherinason hepsetoides	0	0	4.3	35	BP	R
Atherinosoma presbyteroides	16.7	46	146.9	100	BP	R
Stigmatopora nigra	0	4	0	0	BP	T
Stigmatopora argus	0	4	0	0	BP	T
Hippocampus abdominalis	0.6	27	0.2	12	B	R
Gymnapistes marmoratus	0	0	0.3	23	B	R
Pterygotrigla polyommata	0	0	0.8	19	B	TR
Chelidonichthys kumu	0	4	0	0	B	T
Paratrigla papilio	0.1	4	0	4	B	TR
Platycephalus bassensis	0.9	46	3.7	92	B	R
Acanthopegasus lancifer	0	4	0	0	B	T
Dinolestes lewini	0	0	0.1	12	BP	T
Sillago bassensis	0	0	11.2	81	BP	R
Trachurus declivis	0	0	1.0	15	BP	R
Caranx georgianus	1.5	12	5.4	85	BP	R
Arripis trutta	14.1	65	17.8	81	BP	R
Acanthopagrus butcheri	0.2	4	0.1	8	BP	TR
Nemadactylus macropterus	0	0	1.2	27	BP	TR
Aldrichetta forsteri	14.3	62	3.3	81	BP	R
Neoodax balteatus	0	4	0	4	BP	T
Crapatalus arenarius	0	0	0	4	B	T
Pseudaphritis urvillii	0.1	4	0.2	19	B	TR
Cristiceps australis	0	4	0	0	BP	T
Callionymus calauropomus	0	0	0	4	B	T
Nesogobius hinsbyi	0.4	35	2.9	69	B	R
Nesogobius sp. 2	0.5	27	1.1	42	B	R
Thyrsites atun	0	0	0.3	23	BP	R
Seriolella brama	0	0	0.4	8	P	TR
Taratretis derwentensis	0.4	23	0.7	38	B	R
Ammotretis rostratus	6.7	92	8.8	92	B	R
Rhombosolea tapirina	6.9	92	8.9	96	B	R
Brachaluteres jacksonianus	0	4	0	0	BP	T
Aracana aurita	0.1	8	0	0	BP	R
Torquigener glaber	0.2	19	0	0	BP	R
Contusus richei	1.4	35	0.5	31	BP	R
Diodon nicthemerus	0.3	27	1.7	69	BP	R

Fig. 5:3. Species numbers for each size class.

● night. ▲ day. (a) all classes combined; (b) 0 - 99 mm; (c) 100 - 199 mm; (d) 200 - 299 mm; and (e) greater than 300 mm.

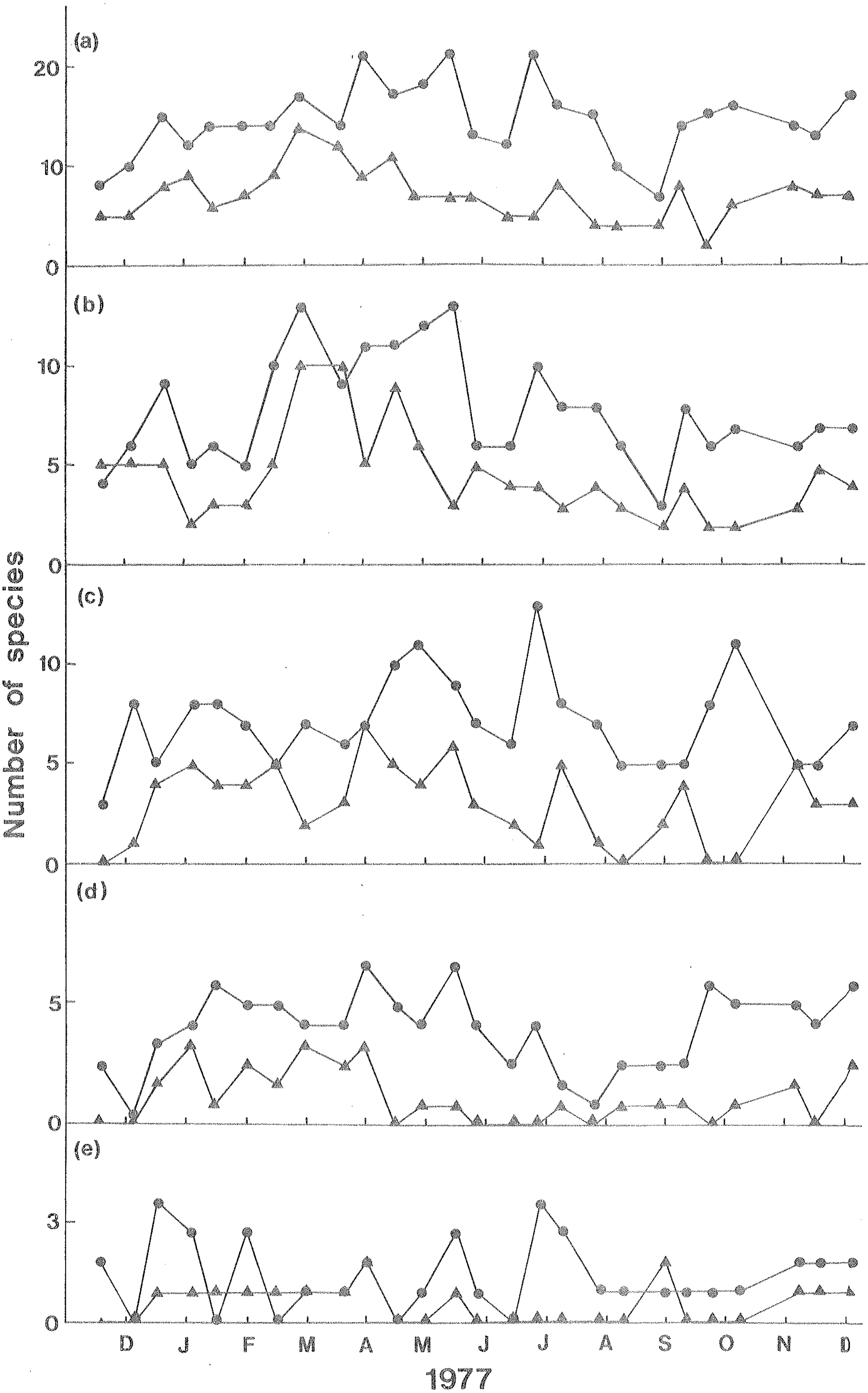

(a)
20
10
0
(b)
10
5
0
(c)
10
5
0
(d)
5
0
(e)
3
0
Number of species
D
J
F
M
A
M
J
J
A
S
O
N
D
1977

Table 5:2a. Numbers of species occuring in each size class at day and night.

	Size Class (mm)				
	0-99	100-199	200-299	>300	Total
Day	21	17	12	5	32
Night	25	20	17	15	41

Table 5:2b. Analysis of variance of the number of species per sample (root transformed) by day/night and season

Source of Variation	Degrees of freedom	Sum of squares	Mean square	F
Day/Night	1	5.74	5.74	30.42***
Season	3	2.46	0.82	4.34**
Diel/Season interaction	3	0.15	0.05	0.26 n.s.
Error	40	7.55	0.19	
Total	47	15.90		

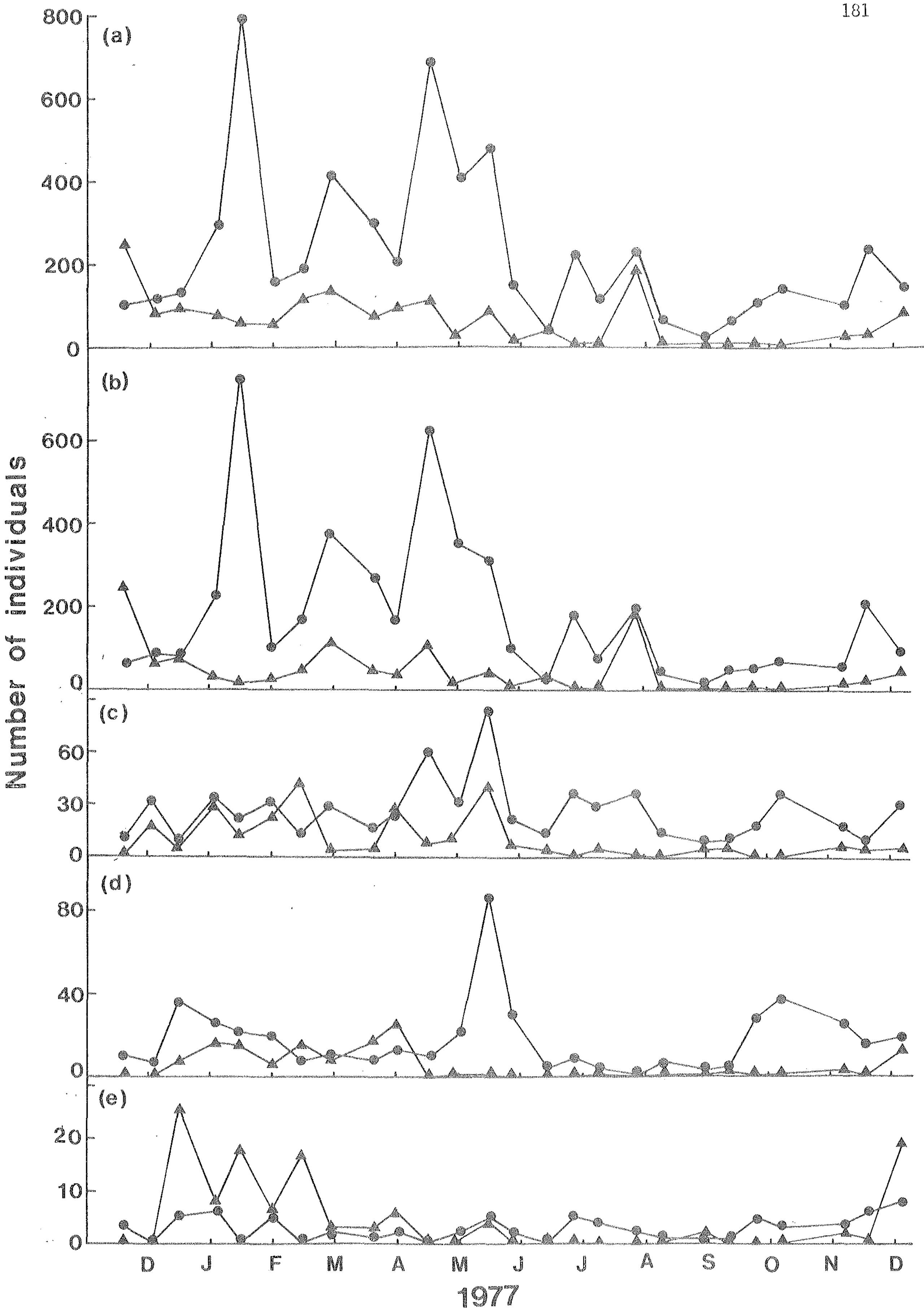
component between seasons; interaction between diel and seasonal factors was not evident (Table 5:2b).

Assessments of fish abundances using nets contain errors introduced from variable working efficiencies and escapement of species. Gear avoidance is closely linked with visibility and size and activity of species, each of which is variable in day-night studies. Net selectivity has received some attention in discussions of sampling methods used in fish population studies (i.e. Talbot, 1955; Springer and McErlean, 1962; Briggs and O'Connor, 1971; Lenanton, 1977; Dybdahl, 1979). McCleave and Fried (1975) suggested that daytime avoidance may be greater for open water trawling than beach seining but commented on the low vulnerability of larger fishes to the latter method. While loss of small post larvae and juveniles through the meshes is likely, underwater observations made on the operating seine net when water transparencies were high, indicated that avoidance by all but very large individuals, was minimal. In fact, as estuarine transparencies are often low (Bayly, 1980), diel activity differences, in larger fishes in particular, may be more important in influencing escapement.

Abundances of individuals were significantly higher at night than day (Fig. 5:4a, Table 5:2c) and the extent of this pattern was largely determined by the abundances of small species (Fig. 5:4b). Large abundance peaks on summer and autumn nights were dominated by the presence of the hardyhead, *Atherinosoma presbyteroides*. This species occupied 26% and 63% of the total abundances for day and night respectively, and was also the most abundant species seined in Cockburn Sound, a marine embayment in Western Australia (Dybdahl, 1979).

The 5 most abundant species at day, *Atherinosoma presbyteroides*, *Aldrichetta forsteri*, *Arripis trutta*, *Rhombosolea tapirina* and *Ammotretis rostratus*, occupied 89% of the total diurnal abundance and were the most

Fig. 5:4. Numbers of individuals for each size class.
● night. ▲ day. (a) all classes combined;
(b) 0 - 99 mm; (c) 100 - 199 mm; (d) 200 - 299 mm;
and (e) greater than 300 mm.



800
600
400
200
0
(a)
(b)
(c)
60
30
(d)
80
40
(e)
20
10
Number of individuals
D
J
F
M
A
M
J
J
A
S
O
N
D
1977

Table 5:2c. Analysis of variance of the number of individuals per sample (log transformed) by day/night and season.

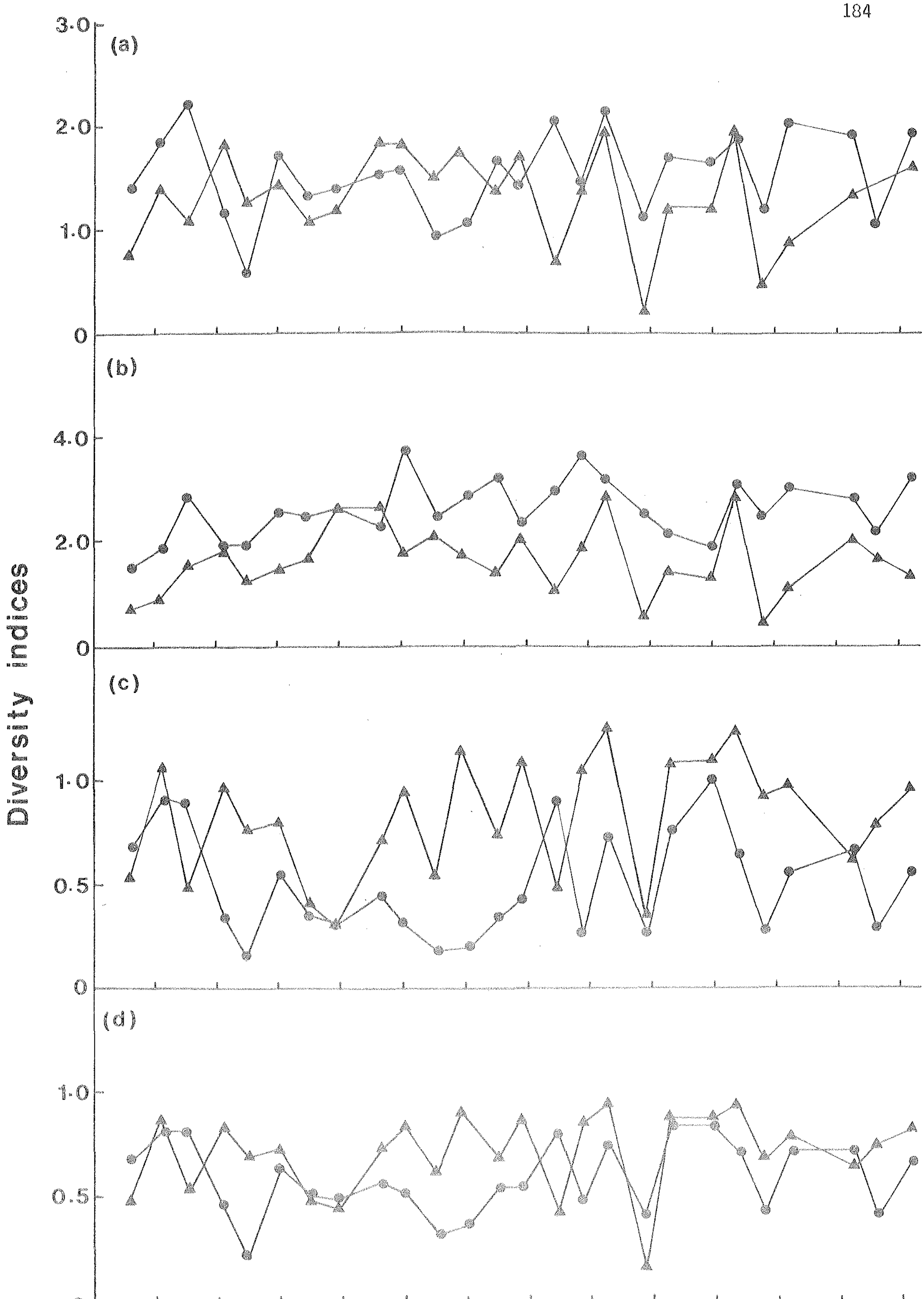
Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Day/Night	1	16.95	16.95	82.33***
Season	3	3.40	1.13	5.50**
Diel/Season interaction	3	0.64	0.21	1.04 n.s.
Error	40	8.23	0.21	
Total	47	29.22		

frequently occurring species (Table 5:3). In comparison, several species were frequent inhabitants of the sandflat at night and of these, *Atherinosoma presbyteroides*, *Arripis trutta*, *Sillago bassensis*, *Rhombosolea tapirina* and *Ammotretis rostratus*, were most abundant.

Larger fishes (Fig. 5:4c-e) were also generally more abundant at night than day. A dramatic increase of large yellow-eyed mullet (*Aldrichetta forsteri*) during day samples in summer (Fig. 5:4e) was the only exception. Johnston (1883) recorded similar seasonal migrations into Tasmanian estuaries during summer and Thomson (1956) noted other non-synchronous patterns in Western Australia.

Seasonal differences in the number of individuals were apparent from the data but there was no evidence to suggest that the seasonal abundances of fishes varied between day and night (Table 5:2c).

Fig. 5:5. Diversity indices calculated from each sample. ● night. ▲ day. (a) Shannon-Weaver index, $\bar{H}$; (b) Species richness index, D; (c) Equitability index, E; and (d) Evenness index, J.


Diversity indices
(a)
3·0
2·0
1·0
0
(b)
4.0
2.0
0
(c)
1·0
0.5
0
(d)
1·0
0.5
0
D J F M A M J J A S O N D
1977

5:4:3 Diversity Indices

Species richness (Fig. 5:5b), which is a function of species numbers, closely followed the pattern of the latter with night 'richer' than day but no clear seasonal trends were evident.

In comparison, equitability (Fig. 5:5c) and evenness (Fig. 5:5d) were higher at day, indicating a more even overall composition during that period. Apart from a minor reduction in equitability during summer and autumn seasonal trends were obscure.

The information index ($\bar{H}$) is often difficult to interpret (Alatalo and Alatalo, 1977). Although species numbers and abundances differed between day and night, no obvious temporal trends were evident from this index (Fig. 5:5a); variations in $\bar{H}$ within periods were greater than variations between periods. This index, although capable of detecting very 'uneven' or 'low richness' samples (i.e. low $\bar{H}$), best characterises the data when used in association with other indices (Dahlberg and Odum, 1970). Several authors have supported use of the information index (Pielou, 1966; Allen and Horn, 1975) but others have questioned the adequacies of some diversity indices (Hurlbert, 1971). Although $\bar{H}$ depends greatly on the abundances of the most common species (Kempton and Wedderburn, 1978), no account is taken of the individual distributional characteristics of these species.

5:4:4 Canonical Variates Analysis

Canonical variates analysis has proved useful where observations on both quantities of different species and environmental factors are concerned (Pielou, 1977). The 17 most abundant and frequently occurring species (Table 5:3) were subjected to 3 analyses to investigate possible temporal occurrence and abundance trends. Seasonal and diurnal patterns of species composition were clearly illustrated.

Table 5:3. Ranking of the 17 most abundant and frequently occurring species. Average numbers of individuals caught per sample in each season for day and night are also given.

Rank	Species	Day (mean number of individuals per sample) Spring	Summer	Autumn	Winter	Number of individuals at day	Night (mean number of individuals per sample) Spring	Summer	Autumn	Winter	Number of individuals at night	Total Number of individuals
1	*Atherinosoma presbyteroides*	33.8	14.9	17.7	1.0	434	65.7	193.0	243.2	70.5	3819	4253
2	*Arripis trutta*	3.3	8.0	11.2	36.0	367	42.5	2.6	22.2	8.8	463	830
3	*Aldrichetta forsteri*	4.8	33.5	12.3	0	372	5.3	4.9	0.7	1.8	86	458
4	*Rhombosolea tapirina*	9.3	11.6	3.5	1.5	179	5.0	15.3	10.0	3.2	231	410
5	*Ammotretis rostratus*	2.2	10.6	9.5	3.0	174	4.3	11.6	15.0	3.3	229	403
6	*Sillago bassensis*	0	0	0	0	0	11.3	8.0	25.0	1.7	291	291
7	*Caranx georgianus*	0.2	0	6.5	0	39	2.2	7.4	5.3	6.0	140	179
8	*Atherinason sp.*	0	0	0	0.2	1	2.5	6.1	11.0	1.0	135	136
9	*Platycephalus bassensis*	0.2	1.0	2.2	0.2	23	1.8	5.4	4.8	2.2	96	119
10	*Atherinason hepsetoides*	0	0	0	0	0	0	4.4	11.5	1.3	112	112
11	*Nesogobius hinsbyi*	0.2	0.1	0.3	1.0	10	2.8	2.9	1.7	4.3	75	85
12	*Pseudophycis bachus*	0	0	0	0	0	2.2	5.8	1.7	2.5	83	83
13	*Diodon nicthemerus*	0.8	0.5	0	0	8	2.8	1.0	2.2	0.8	44	52
14	*Contusus richei*	0	3.1	1.5	0.5	36	0	1.0	0.7	0.3	13	49
15	*Nesogobius sp.* 2	0	0.3	1.2	0.7	13	0.5	0.9	2.7	0.5	29	42
16	*Taratretis derwentensis*	0	0.3	1.3	0	10	0.2	0.4	2.0	0.2	18	28
17	*Hippocampus abdominalis*	0.5	1.4	0	0.3	16	0.5	0	0.2	0.2	5	21

The first analysis (Vb (variables)= 17 species; Gp (groups) = day, night; Vt (variates) = number of individuals; F (F value for inclusion or deletion) = 1) selected for inclusion abundance data from 9 species: *Pseudophycis bachus, Taratretis derwentensis, Aldrichetta forsteri, Atherinason* sp., *Sillago bassensis, Arripis trutta, Nesogobius hinsbyi, Nesogobius* sp. 2 and *Diodon nicthemerus*. A classification determined from squares of the Mahalanobis distances (D^2) indicated that all the day samples and all but 3 night samples were correctly identified. A plot of the canonical variates provided a separation between 'day' and 'night' on the first axis (Fig. 5:6). The results of this analysis, along with the equitability data (Table 5:5c), indicated that night catches are less even than day catches.

A second analysis (Vb = 14 species; Gp = seasons; Vt = number of individuals; F = 1) investigated possible seasonal trends within day samples; *Pseudophycis bachus, Sillago bassensis* and *Atherinason hepsetoides* were absent from all samples and thus were not included in the analysis (see Table 5:3). Five species, *Taratretis derwentensis, Ammotretis rostratus, Rhombosolea tapirina, Caranx georgianus* and *Nesogobius hinsbyi*, contributed to the discriminant functions. A plot of the canonical variates resulted in a rotational arrangement of aggregate groups with sequential seasons adjacent (Fig. 5:7). Winter and spring components were contrasted with 'autumn' on the first axis while 'summer' overlapped the other seasons. The second axis discriminated 'summer' and 'winter', however, the intermediate behaviour of spring and autumn components was exemplified. All samples except 3 were classified according to the correct season (Table 5:4).

A repeat of this analysis for night data using all 17 night variables. with only *Pseudophycis bachus, Taratretis derwentensis, Aldrichetta forsteri, Atherinason* sp., *Sillago bassensis, Arripis trutta, Nesogobius hinsbyi, Nesogobius* sp. 2 and *Diodon nicthemerus* contributing to the

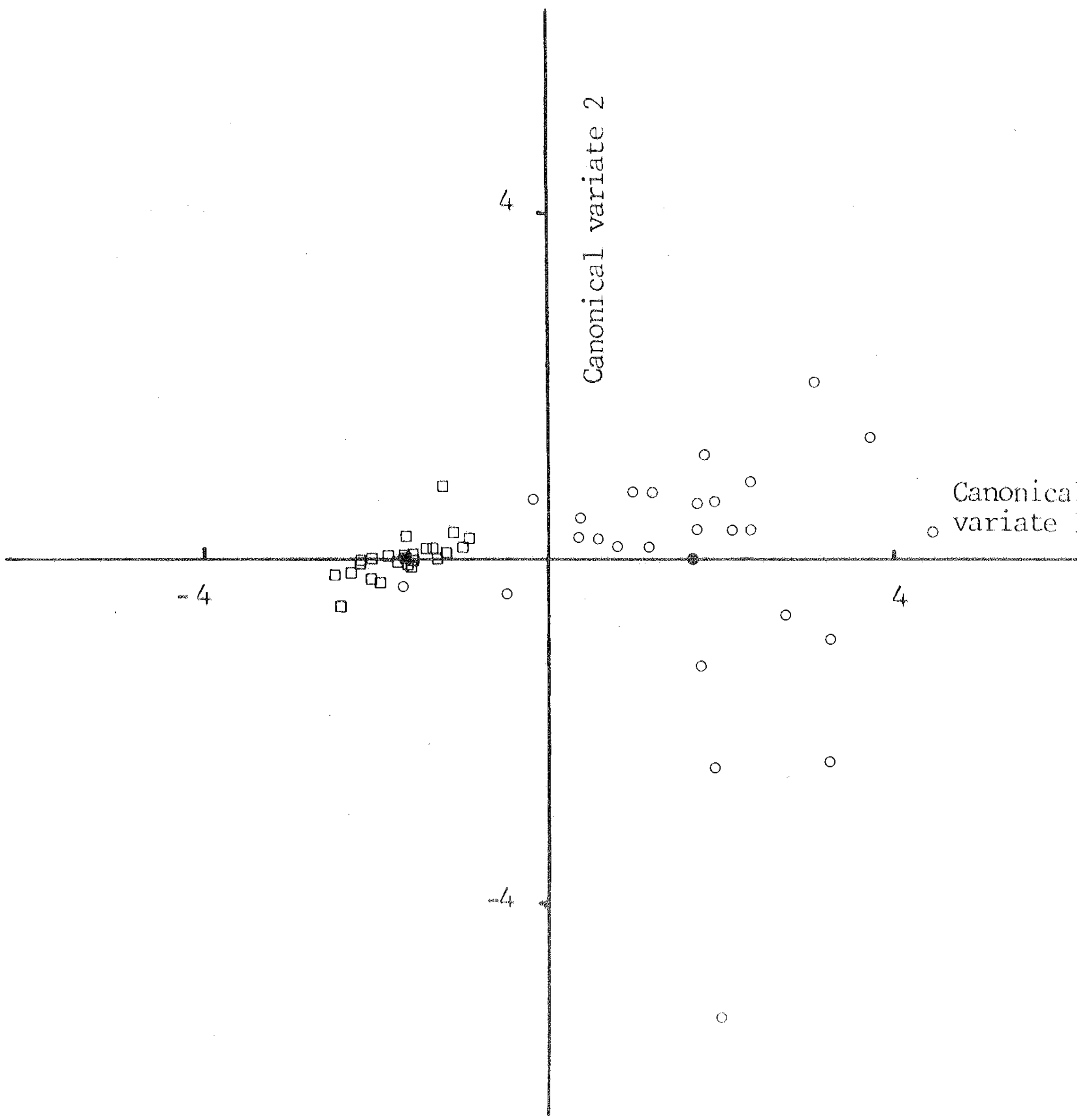


Figure 5:6. Canonical variate analysis of diel variation in occurrence of abundant species. □ day. ○ night. (Solid symbols represent means).

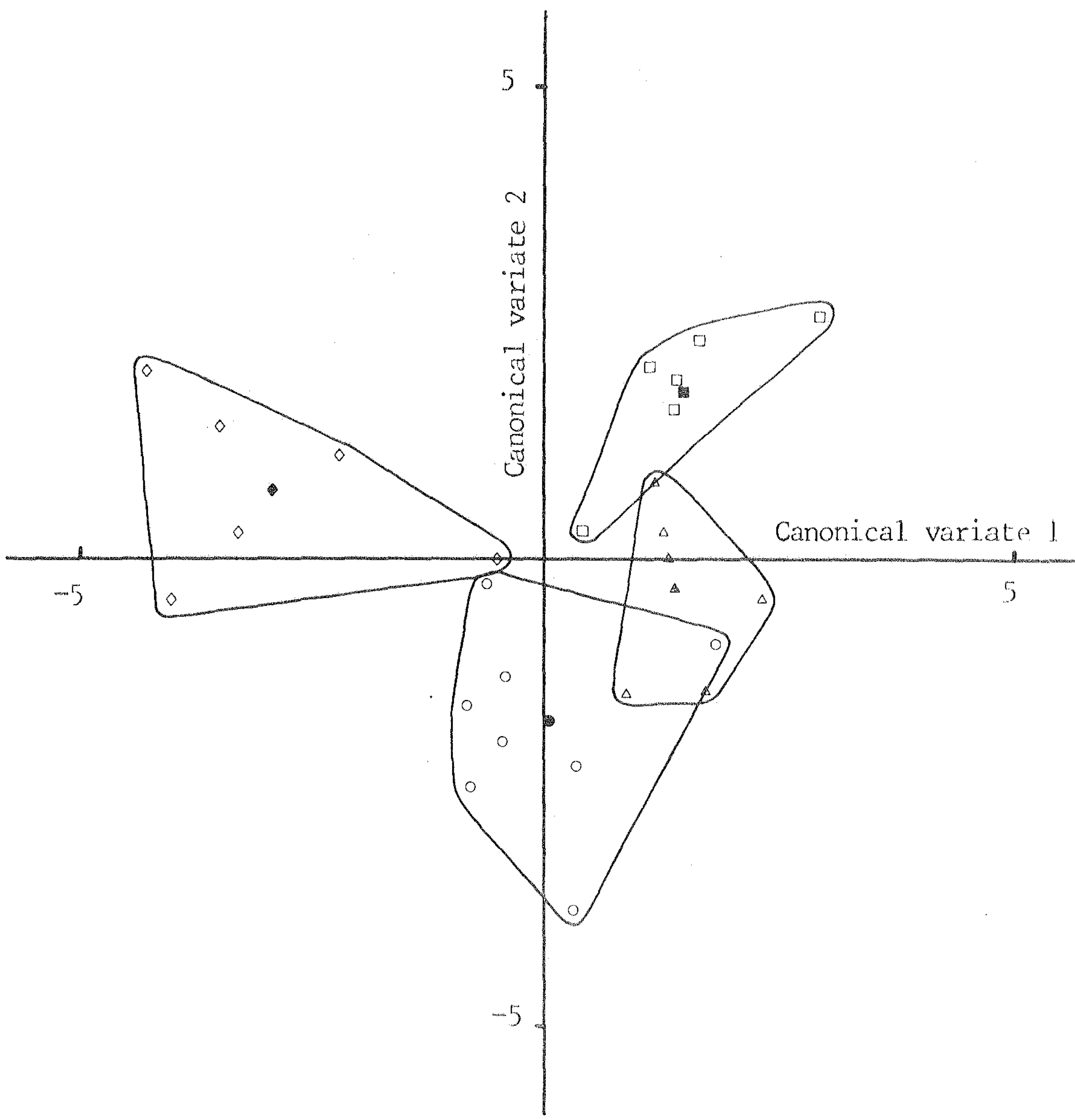


Figure 5:7. Canonical variate analysis of seasonal variation in occurrence of abundant species during day samples.

□ winter. ◇ autumn. ○ summer.

△ spring. (Solid symbols represent means).

Boundary lines are not statistical.

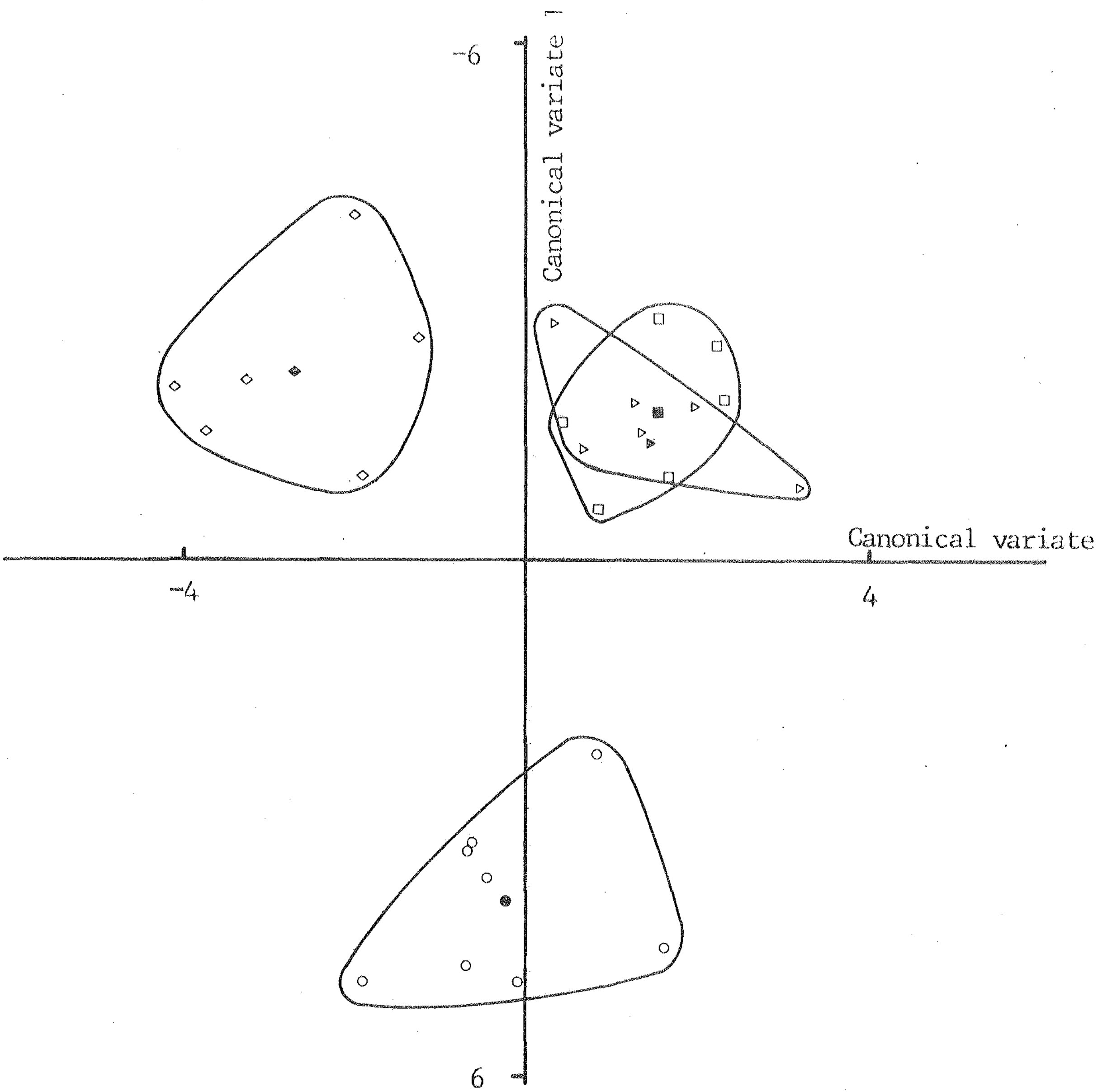


Figure 5:8. Canonical variate analysis of seasonal variation in occurrence of abundant species during night samples.

□ winter. ◇ autumn. ○ summer.

△ spring. (Solid symbols represent means).

Boundary lines are not statistical. Axes have been rotated through 90^{0} to aid comparison with day samples.

Table 5:4. Classification of day samples from each season into a seasonal category based on the probability of resemblance calculated from the D^2 of the discriminant analysis.

Season	Sample number	Probability Spring	Summer	Autumn	Winter	Classif-ication
Spring	1	0.72	0.01	0	0.27	spring
	2	0.86	0.13	0	0.01	spring
	3	0.89	0.03	0	0.08	spring
	4	0.85	0.03	0	0.12	spring
	5	0.75	0.08	0	0.17	spring
	6	0.93	0.07	0	0	spring
Summer	1	0	1	0	0	summer
	2	0.04	0.96	0	0	summer
	3	0.07	0.93	0	0	summer
	4	0	1	0	0	summer
	5	0.03	0.97	0	0	summer
	6	0.20	0.51	0.17	0.12	summer
	7	0.01	0.99	0	0	summer
	8	0.98	0.02	0	0	spring
Autumn	1	0	0	1	0	autumn
	2	0	0	1	0	autumn
	3	0	0	1	0	autumn
	4	0.21	0.64	0.08	0.07	summer
	5	0	0	1	0	autumn
	6	0	0	1	0	autumn
Winter	1	0.05	0	0	0.95	winter
	2	0.02	0	0	0.98	winter
	3	0.03	0	0	0.97	winter
	4	0.02	0	0	0.98	winter
	5	0	0	0	1	winter
	6	0.66	0.14	0	0.20	spring

Table 5:5. Classification of night samples from each season into a seasonal category based on the highest probability of resemblance calculated from the D^2 of the discriminant analysis.

Season	Sample number	Probability Spring	Summer	Autumn	Winter	Classif-ication
Spring	1	0.07	0	0	0.93	winter
	2	0.81	0	0	0.19	spring
	3	0.99	0	0	0.01	spring
	4	0.96	0	0	0.04	spring
	5	0.95	0	0	0.05	spring
	6	0.95	0	0	0.05	spring
Summer	1	0	1	0	0	summer
	2	0	1	0	0	summer
	3	0	1	0	0	summer
	4	0	0.99	0	0.01	summer
	5	0	1	0	0	summer
	6	0	1	0	0	summer
	7	0	1	0	0	summer
	8	0	1	0	0	summer
Autumn	1	0.10	0	0.89	0.01	autumn
	2	0	0	1	0	autumn
	3	0.01	0	0.98	0.01	autumn
	4	0	0	1	0	autumn
	5	0	0	0.99	0.01	autumn
	6	0	0	1	0	autumn
Winter	1	0.02	0	0	0.98	winter
	2	0.54	0	0	0.46	spring
	3	0.13	0	0	0.87	winter
	4	0.07	0	0.01	0.92	winter
	5	0.05	0	0	0.95	winter
	6	0.22	0	0	0.78	winter

discriminant functions yielded similar orientations of seasons but failed to distingiush between spring and winter components (Fig. 5:8). 'Summer' was discriminated from the other seasons on the first axis, while the second axis contrasted 'autumn' and an overlapping 'spring-winter'.

The reliability of these species in indicating seasonal trends in the sampling area was exhibited in Table 5:5 . All summer and autumn samples were correctly classified. Of the remaining winter and spring samples, which were shown in Figure 5:8 to be similar, only 2 were misidentified. In one case, the first sample taken in spring resembled a winter sample. This result is not unreasonable as seasonal trends rarely could be expected to adhere strictly to 3 month periods.

5:4:5 Community Characteristics

The faunal list revealed a high family diversity and a proportionately large ratio of number of families (N_f) to number of species (N_s) (i.e. $N_f/N_s = 0.76$). Of the 38 families represented, 30 were represented by a single species and only 4 by more than 2 species. Hierarchical diversity can be measured by the information index (Pielou, 1977) but few authors have chosen to compare family structuring between fish communities. Warburton (1978), who studied fish populations in a Mexican lagoon, compared results from 4 other studies in the area and the calculated ratios, N_f/N_s, ranged from 0.44 to 0.46; values of N_f ranged from 19 to 31.

The ratio of the number of monospecific families (N_m) to the total number of families was also high (i.e. $N_m/N_f = 0.79$). Calculated ratios determined from faunal lists of other related studies were 0.58 (Thomson, 1959), 0.62 (Warful and Merriman, 1944), 0.63 (Chubb *et al.*, 1979) and 0.69 (Lenanton, 1977). Environments with greater habitat complexity possess more niches and hence the potential for occupancy by greater numbers of species than less complex areas (Barnes, 1974). This principle has been used by Stephenson and Dredge (1976) to explain why some estuaries are richer in species than others nearby. Similarly, in accordance with Gause's hypothesis (Gause, 1935) communities with the greatest complexity of micro-habitats might be expected to possess the greatest potential for radiation of like forms (i.e. congeners and confamilial representatives). Warburton (1978) makes similar inferences while referring to the minimisation of niche overlap by differences in feeding mechanisms and preferences. The comparative environmental uniformity of this sandflat may contribute to the high proportional occurrence of monospecific families.

Summary of the habitat usage by assemblages of species is an important aspect of community studies. Estuaries have been shown by many authors to act as feeding, breeding, growing and predator evasion areas, however, spatial distribution and residency have often been neglected.

The spatial classification of the fauna of a typical sub-tidal sandflat can be divided into benthic, benthopelagic and pelagic components. Due to the close proximity of the bottom,most shore zone fishes are typically demersal. Juveniles of species that normally have pelagic adults (e.g. *Arripis trutta, Trachurus declivis* and *Thyrsites atun*) were observed feeding on, or hovering motionless near, the bottom. Spatial identifications are best viewed as modal or instantaneous characteristics of fishes within specified habitats rather than invariable traits.

Twenty of the species are regarded as benthic (Table 5:1). They consisted of those species capable of burrowing (e.g. *Narcine tasmaniensis, Raja whitleyi, Raja lemprieri, Urolophus cruciatus, Platycephalus bassensis, Acanthopegasus lancifer, Crapatalus arenarius, Taratretis derwentensis, Ammotretis rostratus, Rhombosolea tapirina*) and those that live mainly on the substrate (e.g. *Brachionichthys hirsutus, Hippocampus abdominalis, Gymnapistes marmoratus, Pterygotrigla polyommata, Chelidonichthys kumu, Paratrigla papilio, Pseudaphritis urvillii, Callionymus calauropomus,* *Nesogobius hinsbyi, Nesogobius* sp. 2).

Hyporhamphus melanochir was found only near the surface and together with *Seriolella brama,* which occurred as juveniles in association with jelly fish (*Cyanea* sp.), were the only species categorised as pelagic in this habitat. The remaining 28 species were regarded as benthopelagic.

Distributional patterns within an area, or residency, have been classified into several categories (Warful and Merriman, 1944; Tyler, 1971; Hoese, 1978; Lenanton, 1978) based on time and part of life cycle spent in the area. For this study, as information on the life cycles of many species is unavailable, less speculative time related categories were used. These can be divided into permanently (residents), seasonally (temporary residents) and only occasionally occurring species (transients).

Over half of the species (26) occurring on the sandflat area were residents (Table 5:1) and 16 were found on the sandflat day and night. Several benthic forms and some less mobile species (e.g. *Brachionichthys hirsutus, Hippocampus abdominalis* and *Nesogobius* sp. 2), which were represented by a range of sizes, probably used the area for growth, reproduction and feeding. Benthopelagic forms contained schooling species and these included the most abundant species (e.g. *Atherinosoma prebyteroides, Arripis trutta, Aldrichetta forsteri).* Other species were resident only nocturnally (e.g. *Pseudophycis bachus, Sillago bassensis)* or only diurnally (*Torquigener glaber*).

Temporary residents or seasonal transients consisted of fresh-brackish water invaders during winter and spring (e.g. *Psuedaphritis urvillii*) and marine invaders during summer and autumn (e.g. *Nemadactylus macropterus, Pterygotrigla polyommata, Seriolella brama*). Associated with this latter invasion was a marked increase in the numbers of small species (Fig. 5:3b). This influx of juveniles and stenohaline marine species may be related to the coincidence of the major recruitment period and the greater stability and suitability of physical conditions in the estuary during that period. Lenanton (1977) made similar deductions about the summer occurrences of less euryhaline species in estuaries but emphasised that most juvenile fishes had high salinity tolerances. Similarly, Blaber (1980) suggested that substrate, depth and turbidity may be more important factors than salinity in determining juvenile fish distribution in estuaries. In the absence of salinity tolerance and preference data for most of the species, the importance of salinity remains unresolved.

Transient species were infrequently sampled and were assumed to pass through the area. More intensive sampling, however, may have identified some species as temporary residents or even residents. They consist of marine (e.g. *Raja whitleyi, Chelidonichthys kumu, Dinolestes lewini*), estuarine (e.g. *Acanthopagrus butcheri*), migratory euryhaline freshwater (e.g. *Salmo trutta, Galaxias truttaceus*) and anadromous species (e.g. *Lovettia sealii*). Other species such as *Cristiceps australis* and *Stigmatopora* spp. are found only in association with vegetation (Hoese, 1978) and their presence appeared to be correlated with the co-occurrence of floating seagrasses.

Many authors have expounded theories about the importance of shallow inshore habitats as nursery areas for fish (Barnes, 1974; Hoese, 1978 and others). Seagrass beds have been accredited as the major nursery area (Phillips, 1978), and Wallace and van der Elst (1975) have attributed the high abundance of juvenile fish in South African estuaries to the presence of this vegetation. However, mudflats are also important nursery areas for fishes (Reid, 1954).

An estimated two-thirds (33) of the sandflat species were represented as adults. Thirty-nine species were represented as juveniles and sub-adults and many were young individuals of large commercial species. The adults of *Pseudophycis bachus, Hyporhamphus melanochir, Arripis trutta, Aldrichetta forsteri* and *Seriolella brama* are important to inshore fisheries while *Pterygotrigla polyommata, Platycephalus bassensis, Sillago bassensis* and *Nemadactylus macropterus* are important trawl species on the continental shelf of southern Australia. Adults of *Macruronus novaezelandiae* are common on the continental slope where it is the major species in the trawl fishery of this region (Last and Harris, 1981).

Some of these juvenile trawl species are not found in mainland Australian estuaries. *Nemadactylus macropterus* is caught commercially in New South Wales but does not occur inshore or in estuaries (D. Smith, personal communication). In New Zealand, where the biology of the species has been thoroughly researched, the young occur in depths of 20-45 m (Vooren, 1975). Data from recent Danish seining and trawling surveys (unpublished data) suggest that some nearby marine bays (e.g. Fredrick Henry Bay) act as major nursery areas for some of these species, however, the relative importance of each habitat has not been researched.

The presence of some nocturnal species on the sandflat appears to be related to feeding (e.g. *Sillago bassensis*). Other species, notably most abundant or present only at night (e.g. *Pterygotrigla polyommata, Nemadactylus macropterus*), were found to be inactive. Juveniles of *N. macropterus,* which were frequently found actively schooling around nearby reefs during the day, segregated into vacant hollows in the substrate at night where they became quiescent.

The number of elasmobranch species and their abundances over the sandflat were low and only one shark, *Cephaloscyllium laticeps,* was sampled. Sharks are the largest piscivorous fishes in the estuary and 5 species were collected by Dix (1974) who stated that the estuary is a nursery ground for two species, *Galeorhinus australis* and *Mustelus antarcticus*. Recent gill netting surveys (unpublished data) have shown that two dogfishes, *Squalus acanthias* and *S. megalops*, are also common.

Theories of predator evasion by the utilisation of shallow waters by juvenile fishes have been expounded by several authors (Lenanton, 1977; Hoese, 1978; Warburton, 1978; Blaber, 1980). The prevalence of large active nocturnal carnivores in deeper sections of the estuary may explain the dramatic increase in the numbers and abundances of teleost species on the sandflat at night. Similarly, the observed inactivity at night by some non-burrowing species may also serve to reduce detection by predators.

CHAPTER 6

ASPECTS OF THE ECOLOGY OF FISHES OF THE GREAT SWANPORT ESTUARY

6:1 INTRODUCTION

Lagoons and bay estuaries are the major estuary types in temperate regions of Australia. Although there have been several studies of the fish faunas of warm temperate Australian estuaries (e.g. Thomson, 1957a; 59; Ellway and Hegerl, 1972; Lenanton, 1977, 78; Bell, 1980), published information on cool temperate estuaries is comparatively scant. Robertson (1974), Beumer and Harrington (1977), Robertson and Howard (1978), Robertson (1980) and Rigby (1979) have supplied ecological information on some species found in this province but the habitat usage of fishes throughout one system has not been documented. As mentioned earlier, beach fishes have recieved even less attention.

The Great Swanport Estuary, a large unpolluted lagoon, is comparatively simple in terms of its habitat complexity. The substrate consists mainly of sand or mud but is heavily vegetated in some parts of the estuary. With the exception of the deeper riverine areas and the few small areas of reef, all parts may be seined.

There were several reasons for selecting this estuary, in preference to others, as a study area. Larger bay estuaries situated closer to the laboratory were not considered as suitable sampling areas. They are mostly deep with extensive reef areas and thus are likely to have more complex faunas requiring more complex sampling methods and many more sampling sites. Unlike most smaller lagoons, which also have less complex faunas and which can be sampled using seine nets, the Great Swanport Estuary is large enough to ensure that fish populations would not be altered by a monthly sampling programme. The area is largely accessible by road and there are several boat ramps stationed conveniently about the estuary.

Apart from being an ideal study area, the lagoon is an important recreational and conservation area. The estuary, which is a major breeding area for the black swan (*Cygnus atrata*), was declared a protected area in 1959 (Animal and Birds Protection Board Statutory Rules No. 54). This has since been partly revoked and now only the northwestern section remains a conservation area (National Parks and Wildlife Act, 1970). The major recreational attraction involves angling for black bream, *Acanthopagrus butcheri*.

Biological studies of the fauna of this estuary are limited to work on the breeding of swans (Guiler, 1966, 70). Fulton (1978) has described a galaxiid species, *Galaxias fontanus*, from the upper freshwater zone of the Swan River but the only reference to estuarine fish is in an unpublished manuscript by B. Mollison.

In the present study the environmental characteristics of the estuary are summarised for the first time. Community structure and patterns of abundance and distribution of fishes within the estuary and on the adjacent beach are examined. Habitat usage of these environments by species for growth, reproduction and feeding are also investigated.

6:2 STUDY AREA

The Great Swanport Estuary is a permanently open lagoon, partly enclosed by a bayhead spit, on the eastern Tasmanian coast (Fig. 6:1).

The system consists of a series of shallow embayments and receives runoff from two major rivers and a number of smaller creeks. The total surface area of water at high tide is approximately 4,150 ha (measured by the Tasmanian Lands Department). Several small islands within the estuary occupy a total area of 68 ha. Functionally, the estuary consists of three sections : Great Swanport, Swan River and Moulting Lagoon.

Great Swanport is a 9 km channel separating the Swan River and Moulting Lagoon from the sea. The channel is orientated parallel to a well defined dune system formed by a series of prograding Oligocene beach ridges (Goldin, 1980) and opens into Great Oyster Bay at the eastern end of the spit. Pelican Bay, a small embayment, branches off from the mid-northern area.

The Swan River is the largest stream entering the system and has a drainage area of 44,800 ha (unpublished data, Rivers and Waters Supply Commission). The Wye and Cygnet Rivers are the major tributaries. The river enters King Bay, a moderately large deltoid area, by Tasmanian standards, before draining into the main channel.

Moulting lagoon is a large shallow embayment with an approximate area of 3,000 ha and maximum fetch of about 9.5 km. This section received runoff from the Apsley River via the drains of the Apsley Marshes. The drainage area of the Apsley River and tributaries is approximately 15,500 ha (Anonymous, 1975).

On the ocean side of the spit is a 14 km semi-exposed beach, Nine Mile Beach. The area receives surf from southerly swells but is protected from easterly and northeasterly swells by Freycinet Peninsula and Schouten Island.

The estuary is of major importance recreationally. It is the major locality for bream fishing in Tasmania and is the site of the Australian bream fishing championships. More than 2,000 bream are caught

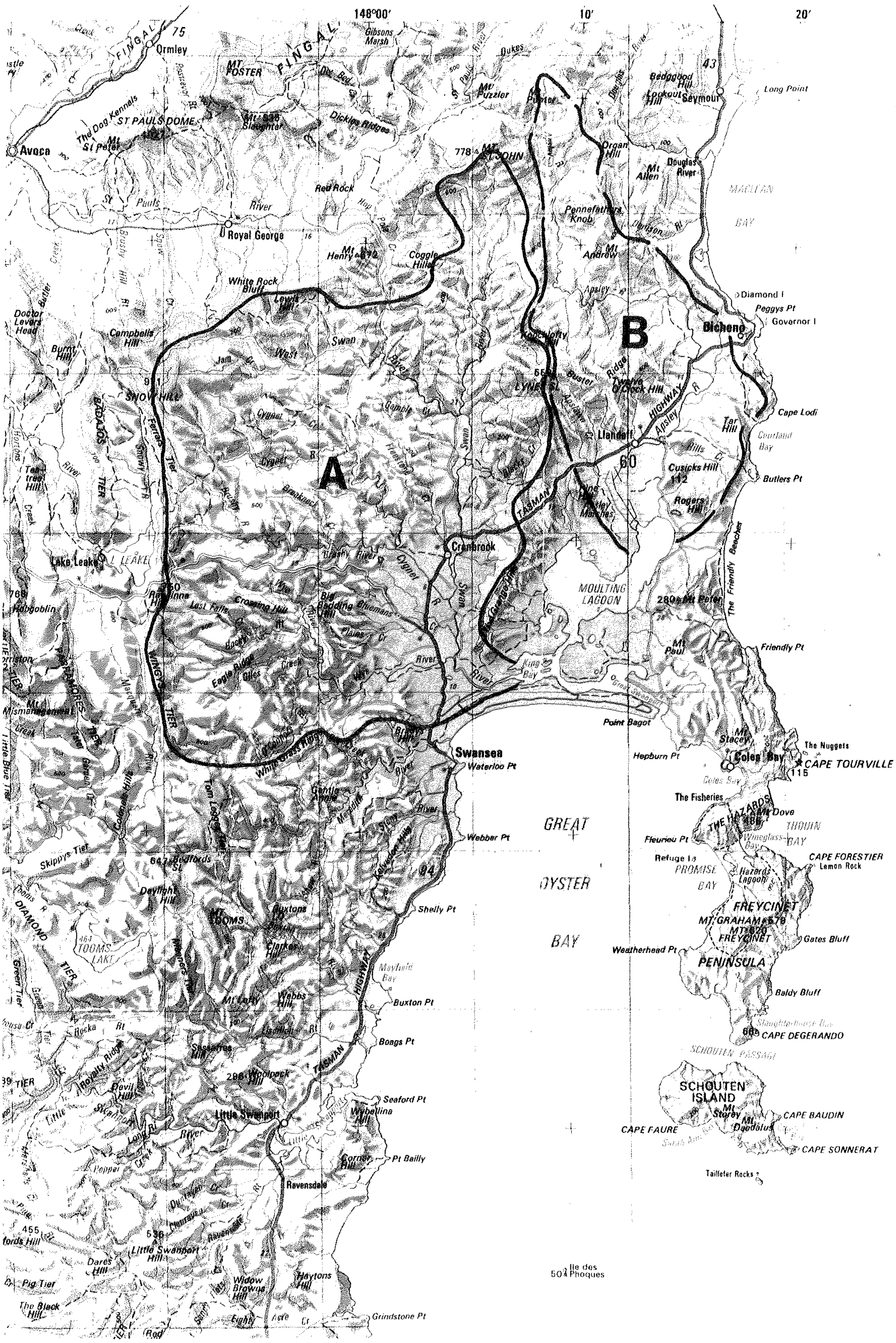


Fig. 6:1. Map of Swanport Estuary showing the catchment area of the (A) Swan and (B) Apsley Rivers.

during these championships which have been held annually since 1956. Smaller quantities of *Arripis trutta, Aldrichetta forsteri* and *Caranx georgianus* are also taken by anglers.

Gill netting and beach seining in the estuary with nets other than 10 m bait nets is illegal (Sea Fisheries Regulations, 1962:33), nevertheless, some poaching with gill nets does occur.

Until recently, the only professional fishery in the estuary was based on eels, *Anguilla australis* and *A. reinhardtii*. Fishing mortality of other species, which are caught incidentally in fyke nets, has not been quantified. Regions of the estuary have now been leased for oyster growing but this operation is unlikely to have an impact on fish populations.

Many species of birds are common around the estuary and several are predatory on fish. The most abundant species include gulls (*Larus* spp.), terns (*Sterna* spp.) and cormorants (*Phalacrocorax carbo* and *P. melanoleucos*). The sea eagle (*Haliaeetus leucogaster*), the pelican (*Pelecanus conspicillatus*), the white-faced heron (*Ardea novaehollandiae*) and the large egret (*Egretta alba*) are larger but less abundant, piscivores.

6:3 METHODS

6:3:1 Field Sampling Procedures

Fish Collections

Fishes were sampled monthly during the day at 7 sites for 13 months commencing in September 1976. Four of these were sampled day and night, within a 24 hour period, on a seasonal basis during 1978.

Sampling sites (Fig. 6:2) were selected from preliminary surveys and incorporated the basic habitat types contained in the lagoon and surrounding beach. These were (1) Nine Mile Beach - semi-exposed beach habitat;

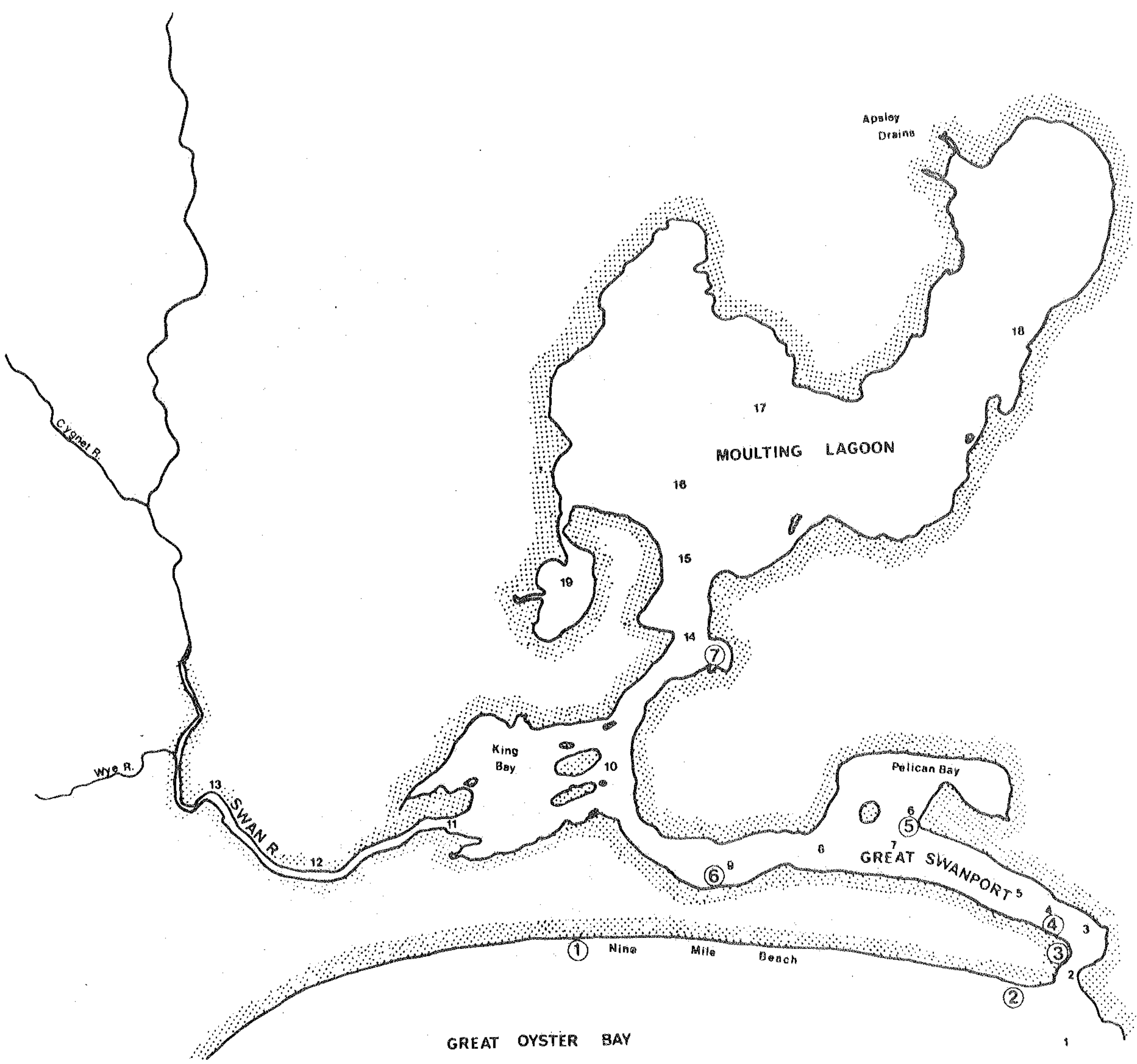


Fig. 6:2. The Great Swanport Estuary and associated waterways. Circled numbers represent monthly sampling sites; uncircled numbers represent seasonal hydrological sampling stations.

(2) Nine Mile Beach - seaward edge of barway; (3) Point Bagot - entrance channel to lagoon; (4) Sandflat - lower region of lagoon (*Zostera* zone); (5) Point Meredith - middle region of lagoon (sparsely vegetated zone); (6) Yellow Sandbanks - middle region of lagoon (*Zostera/Ruppia* transition zone) and (7) Barney Wards Bay - upper lagoon (brackish plant zone, typifying the habitat of Moulting Lagoon and nearby embayments).

The 3 x 35 m beach seine (S1) was used at all sites to obtain quantitative information. Otter trawl (O), gill (G1 and G2) and plankton nets (P) were used to obtain additional qualitative data. All specimens were fixed in 10% formalin and retained for biological analysis.

Underwater Observations

Approximately 60 hours were spent underwater, using SCUBA equipment, examining bottom topography and collecting samples of the substrate and vegetation. Additional notes were taken on the activities and the depth and spatial distributions of fish species.

Physical and Site Data

Temperature, at each sample site, was measured 30 cm below the surface and minimum and maximum salinities were determined from salinity profiles measured by a salinometer. State of sea, water transparency, time of day, tidal reference and wind speed and direction were also recorded.

Sediment samples were collected from different points along a depth profile at each sample site. Particle sizes were determined using a rapid particle analysis described by Holme and McIntyre (1971). The sand fraction was sorted, using a mechanical shaker, through a graded series of standard seives suited to the intervals of the Wentworth scale. The dominant size class was used to characterise sediments at different positions within each sample site.

Salinity and temperature characteristics of the estuary were examined by taking salinity profiles at 19 hydrological sites around the estuary (see Fig. 6:2). Readings were repeated at extreme high and low tides for each season and at high tide during heavy flooding.

Depth profiles of the estuary were determined using a Furuno FG 200 (Mk 3) echo sounder and a plumb line. Transparencies were measured using a Secchi disc.

Other Biological Collections

Small invertebrates were collected in plankton nets, standard F.B.A. nets and hand towed dredges at each sampling site. Additional material, including macroinvertebrates and macrophytes, was collected by diving and from seine samples. This undamaged material provided a reference collection of many prey species encountered in the gut content studies.

6:3:2 Laboratory Procedures

All specimens from each sample were allocated species codes. A maximum of 25 individuals of each species from each sample were measured, weighed and their reproductive states and diets examined. A wide selection of sizes was selected for species represented by more than 25 individuals in a sample. Surplus individuals were measured and assigned to length classes based on 0.5 cm divisions.

Gonad Examination

Gonads were excised, sexed and the stages noted according to a method adapted by Fairbridge (1951). Gonads less than 5 g and greater than 5 g were weighed to accuracies of 0.001 g and 0.01 g respectively.

Diet Examination

Digestive tracts were removed by dissection and the contents of the 'stomach', or the intestinal bulb for stomachless fish, were examined microscopically. The percentage contribution by bulk of the gut content for each food component was estimated following a method used by Last (1975). Low volume items (small in size and few in number) were given a value of 1%. Prey components were identified to the lowest possible taxonomic level and allocated a 3 digit identifier code. A reference collection of these items was stored in 70% ethanol and grouped into higher taxa. Coding of prey groups followed the classification adopted by Barrington (1979) from the Zoological Record (see Appendix 6:3).

The stomach fullness of individuals was classified into one of five categories: (1) empty (E) - containing no ingested material; (2) trace (T) - containing less than 25% by volume of a full stomach or bulb; (3) moderate (M) - containing 25 - 75% of a full stomach or bulb; (4) full (F) - containing 75 - 125% of a full stomach or bulb; and (5) bulging (B) - containing greater than 125% of a full stomach or bulb. A 'full stomach' was defined by a condition whereby the entire length of a stomach or intestinal bulb became extended by pressure from the food components within. The elasticity of the digestive tract of fishes varies with each species so the assessments are likely to be subjective. Nevertheless, these estimates, if used by a researcher with a working knowledge of the species, can be applied meaningfully.

To obtain a guide to the feeding activity of fishes, gut contents were allotted to an abundance class based on the total number of single food items present. These classes were structured as follows :
(1) incidental (i.e. only one prey individual or piece of food present);
(2) frequent (i.e. 2 - 100 individuals and/or pieces present) and (3)

abundant (i.e. more than 100 individuals and/or pieces present). These components were further divided by size. Single food items that exceeded 25% by volume of a full stomach were regarded as large; other items were categorised as small.

6:3:3 Analytical Procedures

Community Score

The objective determination and selection of major species is an inherent problem in presenting specific biological data obtained from faunal studies. Most ichthyologists have given preferential treatment to those species with the greatest abundance (e.g. Tyler, 1971; Webb, 1972, 73a, 73b ; and Wallace and van der Elst, 1975) while some others have provided information on all species (e.g. Springer and Woodburn, 1960; de Sylva, Kalber and Shuster, 1962).

Grange (1979) proposed a simple method of objectively ranking the dominant species in communities. He calculated dominance values, the community scores (C.S.), for species based on the abundance, occurrence and the degree to which they were restricted to a community group. A refined version of this method was used in the present study.

The community score for a species in a community group was determined by the formula:

$$C.S. = (A + B)\ C$$

where A is the occurrence - the percentage of samples from the community group at which the species was collected,

B is the bio-index value standardized as a percentage of the total possible bio-index value and;

C is the fidelity - the weighted proportion of the species' total distribution that occurred in a community group.

The bio-index was obtained by firstly ranking the 10 most abundant species, separately at each sample, from the community group. Ten points were then assigned to the most abundant species, 9 for the second most abundant and so on until the 10^{th} species is given 1 point. The bio-index for a species is the sum of those values from each sample of a community group (Lowry, 1975).

Grange (1979) used an unscaled bio-index value but this could cause the relative contributions of occurrence and abundance information to be disproportioned. Large numbers of samples for a community group could produce very large bio-index values which would completely mask occurrence patterns. For this reason the bio-index was expressed as a percentage of the maximum attainable value (i.e. 10 times the number of samples).

The fidelity was given by McCloskey (1970) as "the degree at which a species is restricted to the community". This approach was followed by Grange (1979), but, although he used the method for comparing different community groups, he did not account for bias caused by unequal numbers of samples in these groups. Consequently a scaled value for fidelity was derived which can be calculated as follows:

$$C_{ij} = \frac{X_{ij}}{\sum_{j=1}^{n} X_{ij}}$$

where C_{ij} is the fidelity of the i^{th} species from community group j,

n is the number of community groups, and

$X_{ij} = m_{ij}/M_{ij}$;

m is the number of species in the j^{th} group at which the i^{th} species occurred and

M is the number of samples in the j^{th} group.

Grange (1979) calculated a maximum value of the community score, the total possible community score (T.P.C.S.), the size of which is dependent on the size of the bio-index value. Because this index was standardised in the present study, the T.P.C.S. is a constant determined by:

$$\text{T.P.C.S.} = (A_{max} + B_{max})\ C_{max} = (100 + 100)\ 1.0 = 200$$

Consequently the community score ratio (C.S.R.) used herein is designated by:

$$\text{C.S.R.} = (A + B)\ C\ /\ 200$$

In accordance with Grange (1979), the two species with the highest C.S.R.'s, or the most dominant species, were regarded as indicator species. 'Dominant species' were those which occurred in over 50% of the samples from a community group and had a community score greater than 25%; those meeting the above criteria and with a community score less than 25% were labelled as 'sub-dominants'. Species occurring in less than 50% of the samples from a community group, but with more than 50% of their distribution in a single group, were defined as 'secondary species'. Collectively, these species are referred to as major species.

Gonadosomatic Indices and Sex Ratios

Gonadosomatic indices (G.S.I.) were calculated by the formula:

$$\text{G.S.I.} = (\text{gonad weight (g)} / \text{total fish weight (g)})\ 100$$

which has been widely adopted (e.g. Le Cren, 1951; Crossland, 1977; Hopkins, 1979; Bell, 1980).

Size at maturity was based on the minimum size at which each sex reached a general G.S.I. value deemed, from staging data, as mature: 2.5 for males and 5.0 for females. Lower indices of maturity, used by Kimura and Suzuki (1981), would not have accommodated latent maturation peaks that were observed in some species. Gonad maturities were occasionally approximated from gonad staging information when insufficient G.S.I. data were available. Bell (1980) found that gonad staging indices could reliably delineate the reproductive cycles of fishes.

Ratios of males to females of each species were also determined. Because the sex ratio of the majority of species approaches unity (Nikolsky, 1963) divergence of this ratio was tested by a χ^2 test (Zar, 1974).

Cluster Analyses

Similarities between sites and food habits of species were examined using two clustering techniques: centroid and furthest neighbour analyses (Alvey *et al.*, 1977). Each analysis was used to examine the continuous (i.e. abundance) and/or binary (i.e. presence/absence) data. Matching zeros were deleted in all situations. These techniques have been explained more fully in Section 4:2:3.

Analysis of Variance

Standard one-way and two-way analyses of variance tests (Sokal and Rohlf, 1969) were used to examine possible variations in numbers of individuals and species by site, season and day/night. Replicates were used where possible. Species numbers and abundance data were normalised using root and log transformations respectively (Sokal and Rohlf, 1969).

6:4 ENVIRONMENTAL CHARACTERISTICS

6:4:1 Depth Profile

The Great Swanport Estuary is mostly shallow and,apart from the lower sections of the Swan River and the lagoon entrance, the main channels are less than 4 m deep at low tide (Fig. 6:3). Large areas of the estuary become exposed as sand or mud flats at low tide and these are most extensive in the lower and middle estuary where tidal ranges are greatest.

Moulting Lagoon is mainly less than 2 m deep but, as the tidal range in this part of the estuary is small, most of its area is permanently submerged.

The Swan River, which has a maximum depth of 15.0 m, is deeper than 8 m for more than 4 km upstream of its delta, King Bay.

6:4:2 Tidal Flow and Water Movements

The rate and direction of water flow in the Great Swanport system appears to be determined by a combination of events controlling conditions in the Swan River and Moulting Lagoon sections and other normal factors influencing tides.

The tidal rhythm in this area is semi-diurnal with significant diurnal inequality. The tidal state is about 2 hours later than the nearest standard port, Hobart, and the range approximated 0.8 m at the estuary mouth and 0.3 m in the upper areas of Moulting Lagoon.

Wind strength and direction are important in determining daily water movements in the estuary. Strong southerly winds drive surface water toward the northern region of Great Oyster Bay and into the estuary. Tides in the basin remain perpetually high while these conditions persist.

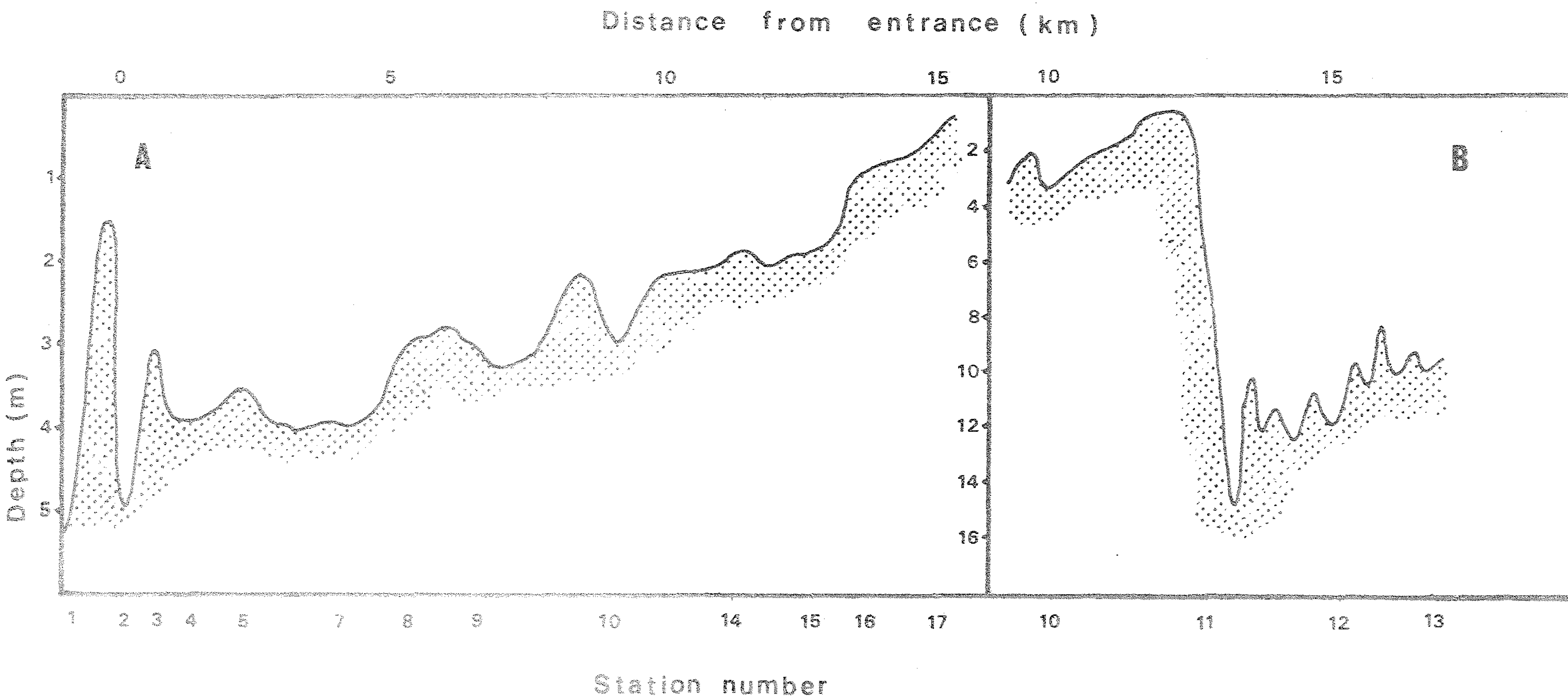


Fig. 6:3. Longitudinal profile of Great Swanport Estuary at low tide (M.L.L.W.), through deepest part of main channel. (A) Swanport-Moulting Lagoon. (B) Swan River.

Similarly, northerly winds push water toward the lower estuary and may reduce the height of tides. Barometric pressures may have similar influences.

The behavioural characteristics of the upper sections of the system are quite different. Water in Moulting Lagoon is mostly maintained with a uniform salinity that is higher on average than in the Swan River. Also, the inward and outward flow of water to Moulting Lagoon is affected largely by the head of water from the Swan River. In wet periods water discharged from the Swan River appears to control the hydrological conditions in the Great Swanport, while in dry periods, when freshwater flow is reduced, Moulting Lagoon exerts the greater influence. A combination of flooding and strong south-westerly winds, however, can cause oligohaline conditions and high water levels to remain in Moulting Lagoon for extended periods (Guiler, personal communication).

6:4:3 Temperature

Water temperatures measured in the estuary ranged from 4.3° - $30.4^{\circ}C$ (7.4° - $27.7^{\circ}C$ at regular sample sites) and these extremes were recorded from the shallow areas where the influence of air temperature changes was maximal. Temperature maxima occurred in February and minima in July (Fig. 6:4). In the main channels, temperatures were less extreme and the largest ranges (6.0° - $23.1^{\circ}C$) were recorded from shallow upper estuary stations (Fig. 6:5).

Thermoclines were frequently detected in the deep narrow region of the Swan River and gradients of $3^{\circ}C$ were recorded in calm autumn periods. In shallow, wide regions of the estuary, however, gradients exceeding $1^{\circ}C$ were seldom observed. The latter areas are more easily mixed by currents and wind generated waves than the more sheltered narrow deeper parts of estuarine systems (Perkins, 1974).

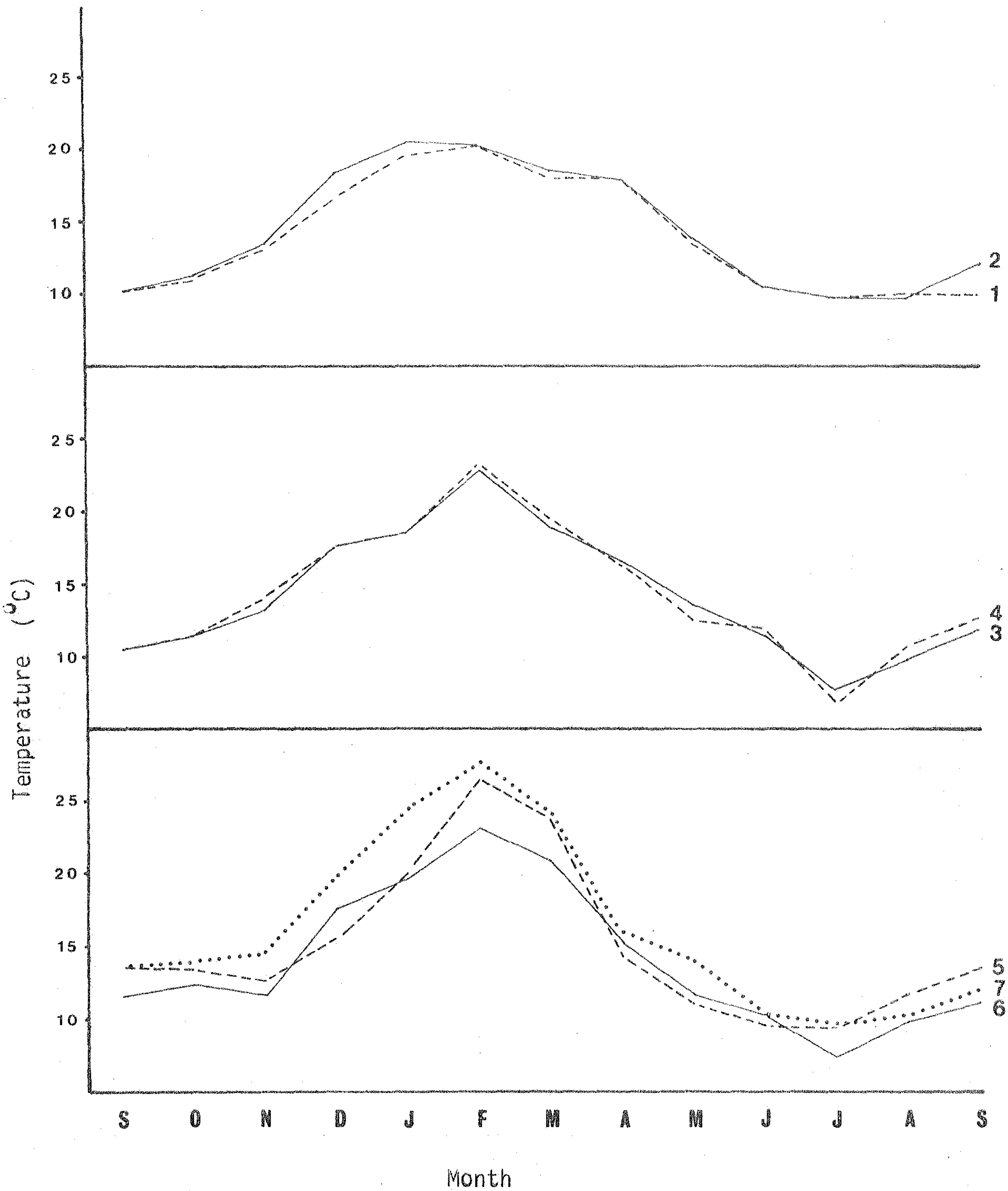


Fig. 6:4. Monthly surface temperatures, between September 1976 and September 1977, at the seven sampling sites: (1,2) beach sites; (3,4) lower estuary sites; (5,6,7) middle and upper estuary sites.

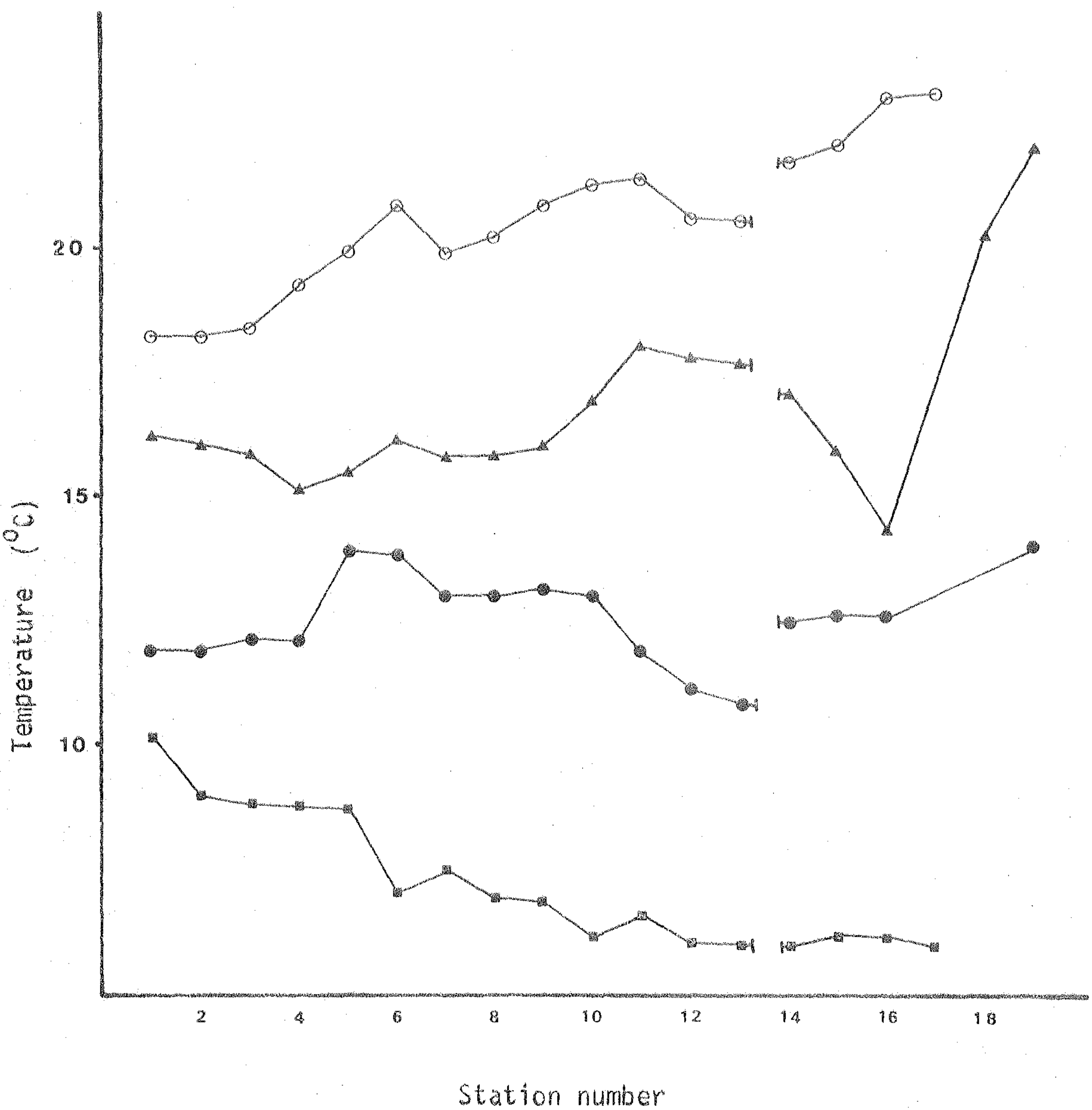


Fig. 6:5. Surface temperature characteristics of the estuary at high tide (M.H.W.) in summer (circles, 24.2.79), autumn (triangles, 4.4.78), winter (squares, 5.7.78) and spring (solid dots, 26.9.78). Stations 14 - 19 represent areas of Moulting Lagoon (see Fig. 6:2).

Temperatures measured in the sea (station 1) were less variable than in the estuary and ranged from 10.1^{o} - $18.2^{o}C$.

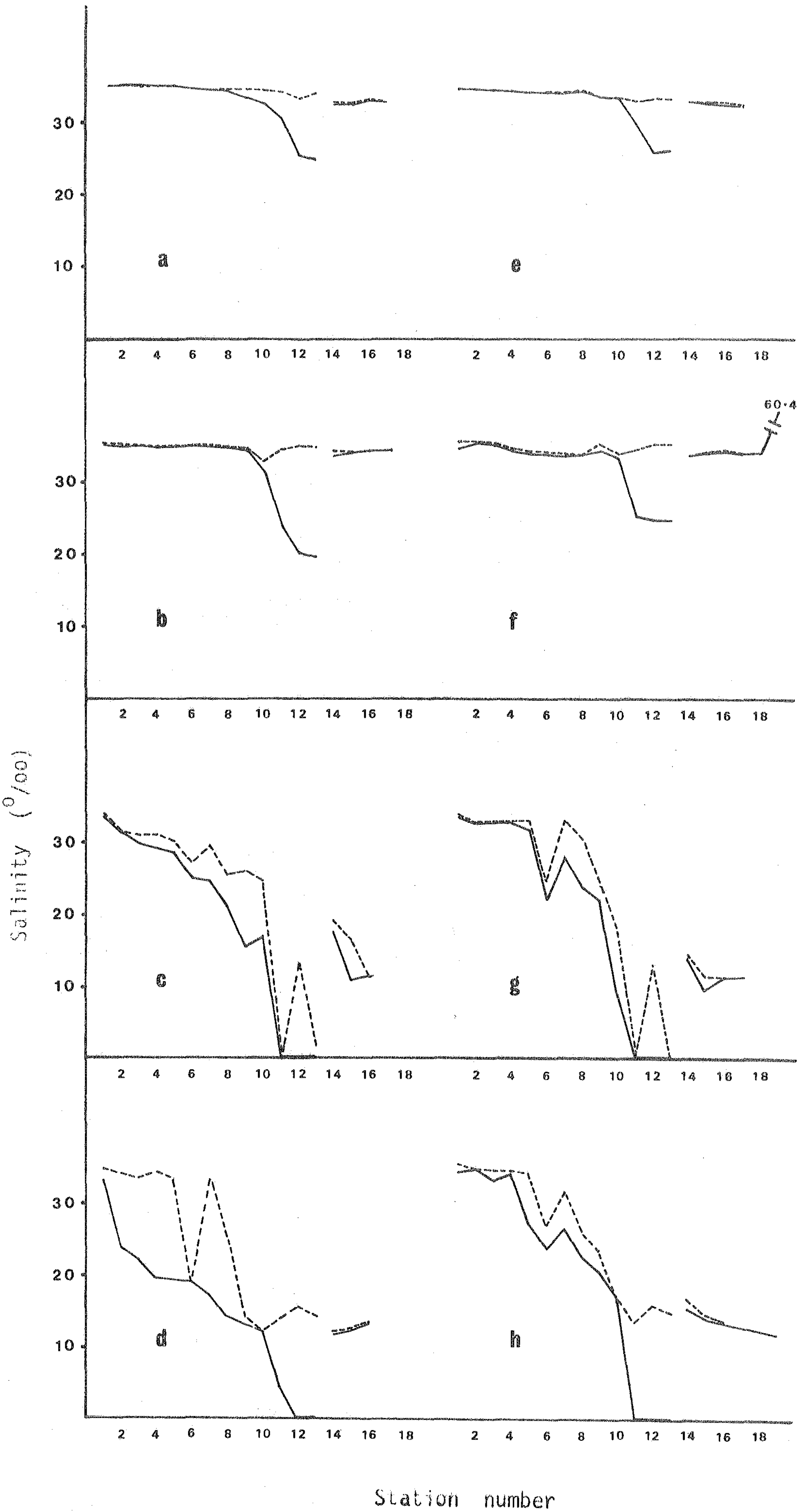
6:4:4 Salinity

The salinity characteristics of this system were complex and variable (Fig. 6:6). During the driest seasons, summer and autumn, water in the estuary was mainly euhaline. Deeper areas of the Swan River were stratified and bottom salinities remained above $30^{o}/oo$. High evaporation in Moulting Lagoon during this period resulted in salinities exceeding the adjacent euhaline seawater. Flow rates of water in some sections of this basin were clearly low as some areas became hypersaline. Little Bay, a small, shallow embayment opening into the southwestern area of the lagoon through a narrow channel, had a salinity of $60.4^{o}/oo$ during autumn.

In the wettest seasons, winter and spring, stratification occurred throughout the estuary. Mesohaline water penetrated deeper areas of the Swan River while surface layers were freshwater or oligohaline. Moulting Lagoon remained typically mesohaline or polyhaline for most of this period. Surface salinities in the Great Swanport increased through entrainment toward the mouth, although anomalies were detected in the shallower secondary channels of Pelican Bay.

During moderate floods, the Swan River discharged large volumes of freshwater into the junction area near King Bay. On the receding tide, this water drained into the sea via Great Swanport and simultaneously prevented the outward flow of the more saline waters of Moulting Lagoon. At this time, conditions in this area of the estuary were generally stable and mostly brackish (Fig. 6:7). In wet years, very heavy rains in the Apsley catchment area may lead to the persistence of oligohaline conditions in Moulting Lagoon.

Fig. 6:6. Salinity characteristics of the estuary at extreme low (a, b, c, d) and extreme high (e, f, g, h) tides in (a, e) summer (24.2.79), (b, f) autumn (4.4.78), (c, g) winter (5.7.78) and (d, h) spring (26.9.78). Maximum and minimum salinities are denoted by broken and unbroken lines respectively. Low station numbers represent areas near the estuary mouth; stations 14 - 19 represent areas of Moulting Lagoon (see Fig. 6:2).


Salinity (°/oo)
30
20
10
a
e
b
f
c
g
d
h
60·4
2 4 6 8 10 12 14 16 18
Station number

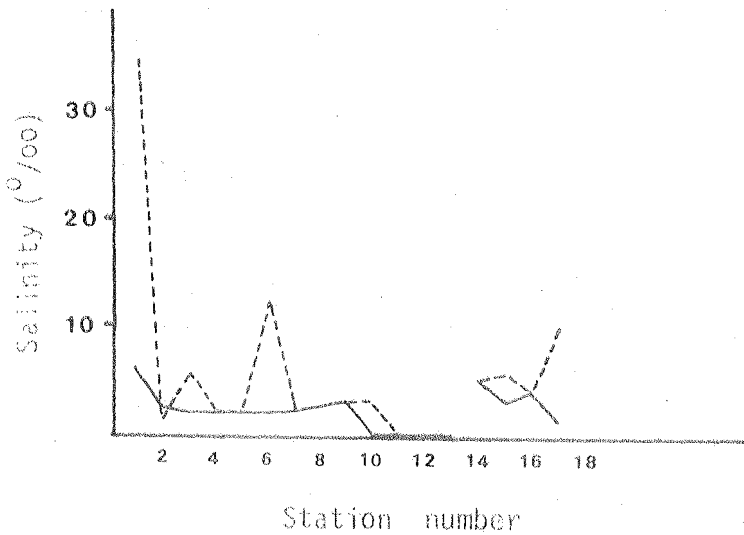


Fig. 6:7. Salinity characteristics of the estuary during flooding (7.6.78). Bottom and surface salinities are denoted by broken and unbroken lines respectively.

6:4:5 Vegetation

Zostera muelleri was the dominant macrophyte in the middle and lower sections of the estuary. Near the entrance, where currents were fast, the channel bottom was scoured and devoid of vegetation, although along channel edges, where sands were more consolidated, *Zostera* stands of variable length were prolific. This plant also occurred in the short-leafed form on the intertidal flats of Great Swanport. Densest stands were found in the middle areas of the Great Swanport where the long-leafed form dominated the relief and also extended into the main channel. In shallow sub-tidal and other more sheltered middle areas, mixed stands of *Zostera* and *Ruppia maritima* were characteristic, however, *Heterozostera tasmanica* was not common in this estuary.

Small stands of *Enteromorpha* sp. were found intertidally in the middle areas of the Great Swanport but other attached algae were poorly represented. Their absence was replaced by a seasonally fluctuating biomass of epiphytic red algae, of which *Polysiphonia* sp., *Cladophora* sp. and

Ceramium sp. were dominant genera.

The Swan River delta was vegetated with mixed stands of *Zostera* and *Ruppia*. Freshwater plants, such as *Myriophyllum* spp., and filamentous green algae were dominant along the banks in lower parts of the river.

Moulting Lagoon was densely vegetated with a variety of plants dominated by *Ruppia; Triglochin striata, Potamogeton* spp. and *Lepilaena* sp. were also abundant. *Chara nitella* and other filamentous greens and epiphytic reds were the dominant algal macrophytes.

The beach had no attached vegetation but detached seagrasses from the estuary and kelps, such as *Macrocystis* from nearby reefs, often occurred subtidally in aggregations after storms.

6:5 FAUNAL CHARACTERISTICS OF FISHES

6:5:1 Species Composition and Occurrence

Fifty-four of the 59 species recorded from the estuary and surrounds were collected from quantitative samples (Appendix 6:1). The number of species differed significantly for season and between sampling sites (Table 6:3a). More species were taken from the middle and lower estuary sites than from the upper estuary or beach sites (Table 6:1) which is supported by data in Section 4:4. The presence of seagrass stands at sites 4 and 6 and their absence at site 5 may explain the lower relative number of species observed at the last site. The number of species in samples was generally highest in summer and autumn and lowest in winter and spring. There was insufficient evidence of an interaction between seasons and sites.

The overall compositional characteristics of the fauna varied between the sites. Species such as *Syngnathus tuckeri, Sillago bassensis, Mugil cephalus, Crapatalus arenarius* and *Ammotretis liturata* were only collected

Table 6:1. : Numbers of individuals and species sampled from the Great Swanport Estuary. S_m denotes the composition of species from similar habitats in Chapter 4.

	Site No.	Number of species					Number of individuals		
		Monthly samples (1976-77)	Seasonal samples (1978) Day	Seasonal samples (1978) Night	All samples	Proportion of S_m	Monthly samples (1976-77)	Seasonal samples (1978) Day	Seasonal samples (1978) Night
Beach	1	11	-	-	22	0.82	749	-	-
	2	17	12	11			1287	1002	155
Estuary	3	17	16	16	49	0.78	3999	1315	633
	4	30	27	23			8157	3087	1451
	5	19	-	-			4604	-	-
	6	24	18	17			5984	2969	968
	7	16	-	-			11875	-	-
Total		45	36	35	54		36655	8373	3207

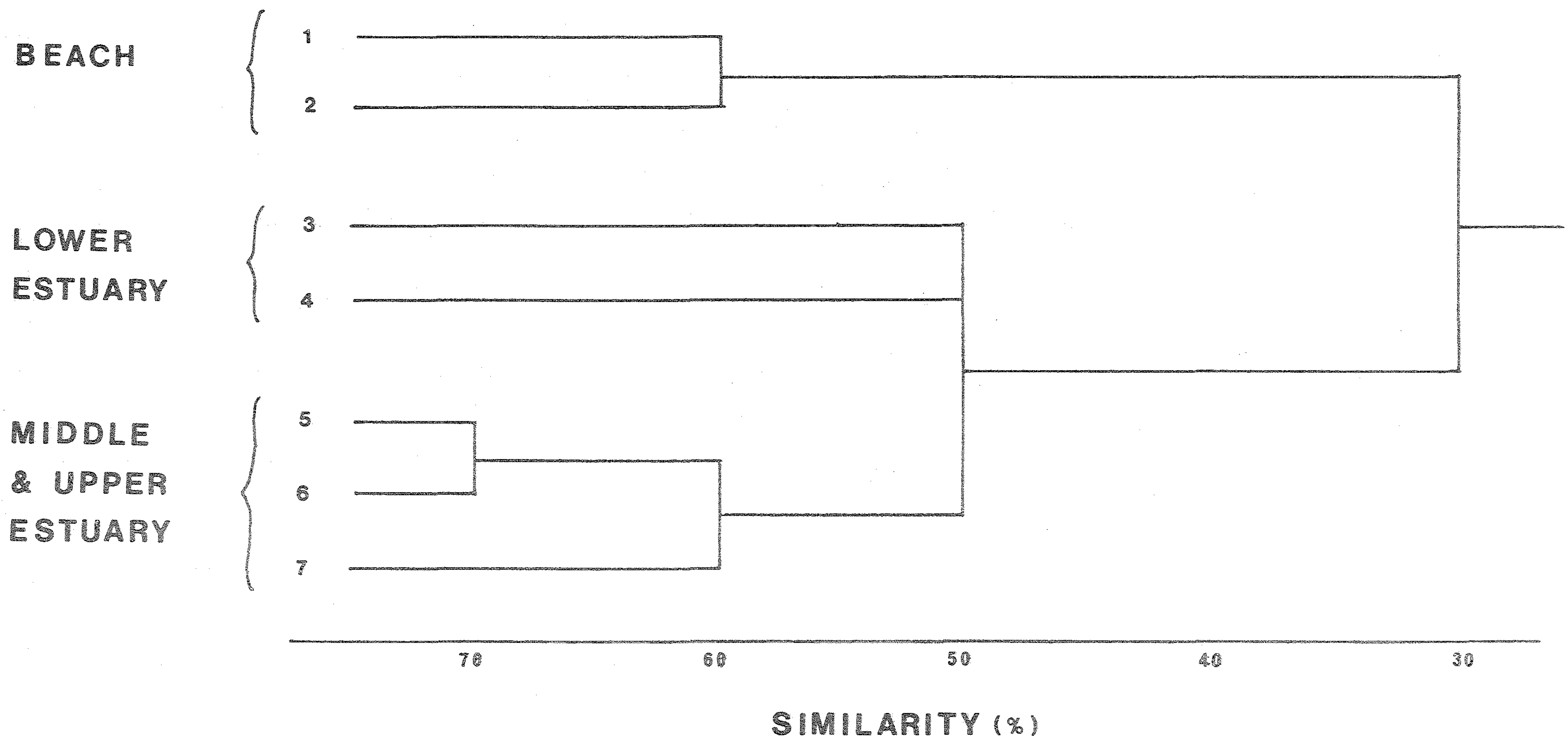


Fig. 6:8. Dendrogram showing similarity in the composition of fish species at each of the 7 sampling sites in the Swanport Estuary and environs.

at beach sites, while 36 species were only collected in the estuary.

Subtle patterns emerged as clear compositional trends were evident between sites. Centroid cluster analysis, based on overall presence/absence of species per site, showed some association between adjacent sites but divided the fauna into 3 groups: a beach assemblage; a lower estuary assemblage; and an assemblage in the middle and upper estuary (Fig. 6:8). Furthermore, the estuarine fauna was distinct from the beach fauna. Identical site relationships were obtained from furthest neighbour cluster analysis.

The similarity matrix (Appendix 6:2) indicated that the faunas of beach sites were mutually similar but both differed in composition to the faunas of the estuarine sites; of these the 'channel' (site 3) was most similar to the beach sites. The site with the most species, site 4, exhibited greatest similarity to the other locality where seagrasses were abundant (site 6) and thereafter to the other lower estuary sites. The composition of species occurring at site 7 most clearly resembled sites 5 and 6.

The species that occurred at the beach sites typified those found in similar habitats elsewhere around Tasmania (see Section 4:4). *Crapatalus arenarius, Arripis trutta* and *Aldrichetta forsteri* were the most common beach species (Table 6:2). Weed-dwelling species such as *Stigmatopora nigra, Urocampus carinirostris* and *Cristiceps australis* were all recorded together amongst detached seagrass in a site 2 sample taken at low tide after heavy rain. Salinity conditions at the time of sampling were polyhaline and the individuals were presumably carried into the area by the ebbing tide. Other occurrences of *S. nigra* appeared to be associated with the simultaneous presence of *Zostera*.

Detached seagrasses were seldom found at site 1 as the main direction of longshore drift along Nine Mile Beach is from west to east. Consequently

Table 6:2 : Rank of the five most abundant and frequently occurring species from the beach and estuary sites during 1976/77

Rank	Species	Occurrence (%)	Rank	Species	Abundance (Number of individuals)
SITE 1					
1	*Crapatalus arenarius*	92	1	*Aldrichetta forsteri*	321
2	*Arripis trutta*	62	2	*Arripis trutta*	284
3	*Aldrichetta forsteri*	46	3	*Crapatalus arenarius*	98
	Ammotretis liturata	46	4	*Ammotretis liturata*	21
5	*Syngnathus tuckeri*	31	5	*Syngnathus tuckeri*	13
SITE 2					
1	*Arripis trutta*	85	1	*Arripis trutta*	393
	Crapatalus arenarius	85	2	*Aldrichetta forsteri*	311
3	*Aldrichetta forsteri*	62	3	*Hyporhamphus melanochir*	241
4	*Stigmatopora nigra*	54	4	*Atherinosoma presbyteroides*	170
5	*Rhombosolea tapirina*	46	5	*Crapatalus arenarius*	45
SITE 3					
1	*Rhombosolea tapirina*	92	1	*Atherinosoma presbyteroides*	1777
2	*Aldrichetta forsteri*	85	2	*Aldrichetta forsteri*	705
	Ammotretis rostratus	85	3	*Ammotretis rostratus*	455
4	*Atherinosoma presbyteroides*	77	4	*Hyporhamphus melanochir*	330
5	*Nesogobius sp. 2*	62	5	*Rhombosolea tapirina*	247
SITE 4					
1	*Nesogobius sp. 2*	100	1	*Atherinosoma presbyteroides*	2870
2	*Favonigobius tamarensis*	92	2	*Aldrichetta forsteri*	2593
3	*Aldrichetta forsteri*	85	3	*Atherinosoma microstoma*	1374
4	*Atherinosoma presbyteroides*	77	4	*Stigmatopora nigra*	294
	Stigmatopora nigra	77	5	*Favonigobius tamarensis*	248
	Rhombosolea tapirina	77			
SITE 5					
1	*Atherinosoma microstoma*	100	1	*Atherinosoma presbyteroides*	2622
	Aldrichetta forsteri	100	2	*Atherinosoma microstoma*	800
	Rhombosolea tapirina	100	3	*Aldrichetta forsteri*	635
4	*Favonigobius tamarensis*	92	4	*Favonigobius tamarensis*	228
5	*Atherinosoma presbyteroides*	77	5	*Rhombosolea tapirina*	151
SITE 6					
1	*Atherinosoma microstoma*	100	1	*Atherinosoma microstoma*	4319
2	*Aldrichetta forsteri*	92	2	*Atherinosoma presbyteroides*	700
3	*Favonigobius tamarensis*	85	3	*Aldrichetta forsteri*	378
	Urocampus carinirostris	85	4	*Favonigobius tamarensis*	181
5	*Atherinosoma presbyteroides*	77	5	*Stigmatopora nigra*	98
	Gymnapistes marmoratus	77			
	Pseudaphritis urvillii	77			
SITE 7					
1	*Atherinosoma microstoma*	100	1	*Atherinosoma microstoma*	11474
2	*Aldrichetta forsteri*	85	2	*Aldrichetta forsteri*	155
3	*Pseudogobius olorum*	77	3	*Pseudogobius olorum*	78
4	*Pseudaphritis urvillii*	62	4	*Gymnapistes marmoratus*	49
	Favonigobius tamarensis	62	5	*Pseudaphritis urvillii*	41

estuarine species were largely absent from samples taken in this area. Detached macrophytic brown algae were abundant subtidally after strong storms. *Contusus richei, Syngnathus tuckeri* and *Cristiceps australis,* which also inhabit weedy marine reef environments, occurred in abundance on the beach during these periods. Additional seine and dip net samples taken through these kelp masses indicated that they possessed prolific invertebrate faunas which could provide an additional food source for fish using this habitat.

The fish faunal characteristics of this estuary were similar to those of other open lagoons (see Section 4:4:2). Euryhaline marine and estuarine components were clearly evident (see Table 6:2). The widespread species, *Rhombosolea tapirina, Aldrichetta forsteri, Ammotretis rostratus, Atherinosoma presbyteroides* and *Nesogobius* sp. 2, were the most common fishes at the entrance of the estuary (site 3). As current speeds were highest at this locality, the most successful species were active free swimmers and burrowing flatfishes. The occurrence of weed-preferring species such as *Cristiceps australis, Stigmatopora nigra* and *Acanthaluteres spilomelanurus* also appeared to be linked with the presence of drifting *Zostera.*

Based on frequency of occurrence, gobiids were the dominant species found at site 4. Lower current speeds plus the extensive growth of *Zostera* at this site probably contributed to the higher occurrence of species such as *Stigmatopora nigra, Gymnapistes marmoratus, Nesogobius* sp. 2 and *Favonigobius tamarensis.* Less than a third of the species caught at this site were found in more than half the samples and more than a third were only recorded from a single sample.

Atherinosoma microstoma and *Aldrichetta forsteri* were the most frequent occurring species at the upstream sampling areas (sites 5 - 7). The composition of species at site 5 was characterised by lower occurrences of weed-dwelling species. Of these, *Urocampus carinirostris, Stigmatopora nigra* and *Gymnapistes marmoratus* were rarely found, while *Cristiceps australis, Acanthaluteres spilomelanurus* and *Meuschenia freycineti* were never collected.

The composition of species at site 7 was characterised by a reduction in the number of euryhaline marine species and an increase in the occurrence of estuarine species. Marine species commonly collected at the lower estuarine sites, but absent from site 7, included *Stigmatopora nigra, Neoodax balteatus, Nesogobius* sp. 2 and the monacanthid species.

6:5:2 Relative Abundance

The total numbers of individuals sampled varied significantly between sites (Table 6:3b) These were lower at the beach sites than at any of the estuarine sites, and higher at the vegetated sites (sites 4 and 6) than at non-vegetated sites (sites 3 and 4) in the middle and lower estuary (see Table 6:1). Barney Wards Bay (site 7) had the largest number of individuals of which about 97% were *Atherinosoma microstoma*.

Benthopelagic and pelagic schooling species were most numerous at both beach and estuarine situations. This niche has been occupied by species from 4 major groups: Mugilidae, Arripidae, Atherinidae and Hemiramphidae.

The abundance rank of species at each site is given in Table 6:2. *Aldrichetta forsteri* was among the most abundant species both at beach and estuarine sites. *Arripis trutta* was most abundant at beach sites while *Atherinosoma presbyteroides* was the most abundant species in the lower estuary (sites 3 and 4) and at site 5. *Hyporhamphus melanochir* was an important component near the entrance to the estuary (sites 2 and 3). *Atherinosoma microstoma* was clearly the most abundant species at the most brackish sites (sites 6 and 7).

Table 6:3a. Analysis of variance of the number of species per sample (root transformed) by season and site.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling sites	6	19.20	3.20	21.24***
Seasons	3	2.46	0.82	5.45**
Site/season interaction	18	2.89	0.16	1.06 n.s.
Error	56	8.44	0.15	
Total	83	32.99		

Table 6:3b. Analysis of variance of the number of individuals per sample (log transformed) by season and site.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling sites	6	19.28	3.21	13.35***
Seasons	3	1.64	0.55	2.27 n.s.
Site/season interaction	18	2.99	0.17	0.69 n.s.
Error	56	13.48	0.24	
Total	83	37.39		

Table 6:3c. Analysis of variance of the number of species per sample (root transformed) by day/night and site.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling sites	3	6.97	2.32	7.02**
Day/night	1	0.11	0.11	0.32 n.s.
Site/diel interaction	3	0.10	0.03	0.10 n.s.
Error	24	7.94	0.33	
Total	31	15.11		

Table 6:3d. Analysis of variance of the number of individuals per sample (log transformed) by day/night and site.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling sites	3	4.88	1.63	6.37**
Day/night	1	0.58	0.58	2.27 n.s.
Site/diel interaction	3	0.12	0.04	0.16 n.s.
Error	24	6.13	0.26	
Total	31	11.71		

Table 6:3e. Analysis of variance of the number of individuals of *Atherinosoma* spp.(log transformed) by day/night and site.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling sites	3	1.56	0.52	2.87 n.s.
Day/night	1	1.17	1.17	6.44 n.s.
Error	3	0.54	1.18	
Total	7	3.28		

Table 6:3f. Analysis of variance of the number of individuals (log transformed) with *Atherinosoma* spp. excluded by day/night and site.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling sites	3	0.31	0.10	8.83 n.s.
Day/night	1	0.01	0.01	1.22 n.s.
Error	3	0.04	0.12	
Total	7	0.36		

Fig. 6:9. Relative abundances of atherinids (A, B), a mugilid (C), and gobiids (D, E, F) at the 7 sampling sites. Data is expressed as a proportion of the total number of individuals sampled (n).

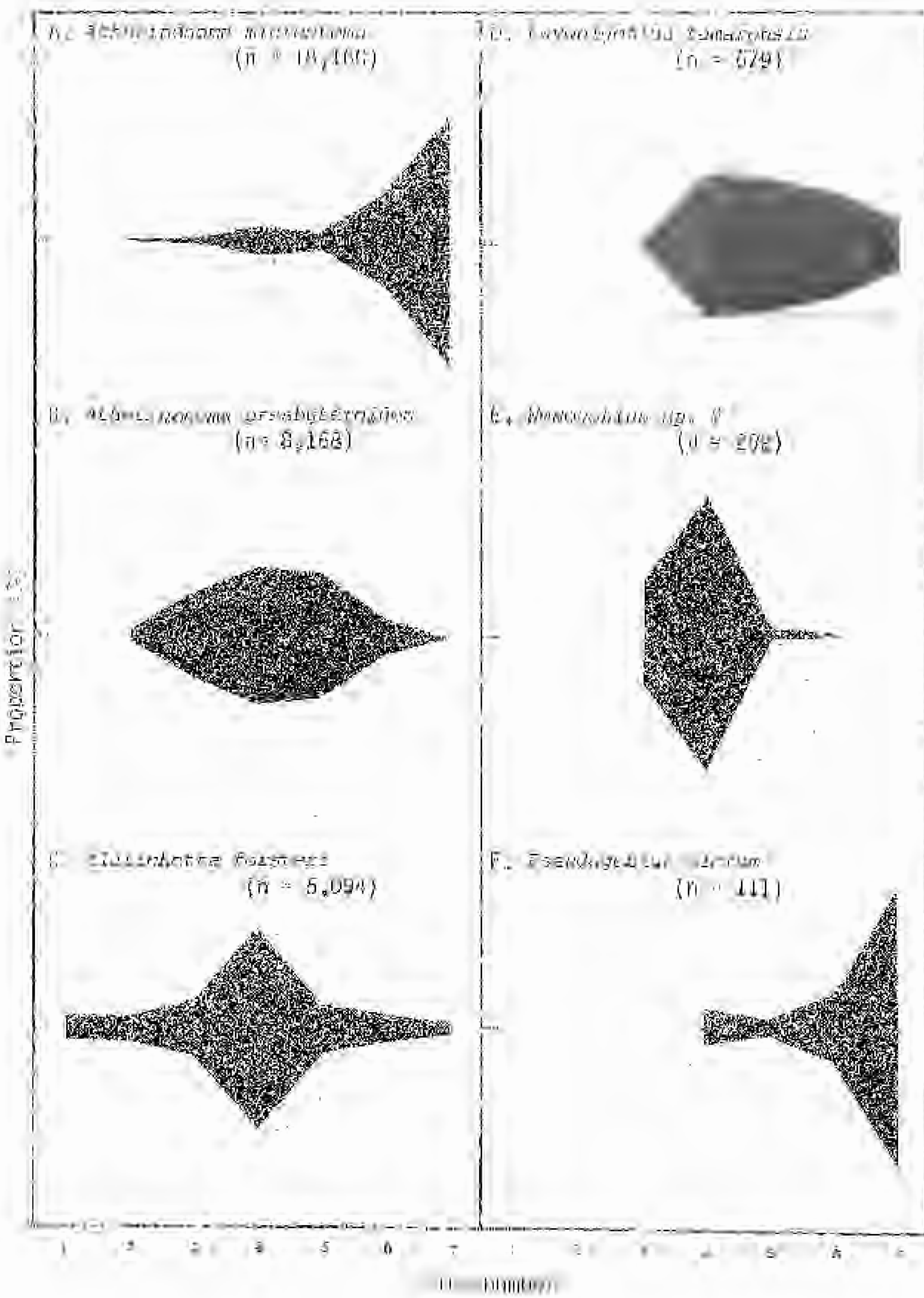

(n = 8,168)
(n = 5,094)
(n = 679)
Proportion

Fig. 6:10. Relative abundances of pleuronectids (G, H, I) and syngnathids (J, K, L) at the 7 sampling sites. Data is expressed as a proportion of the total number of individuals sampled (n).

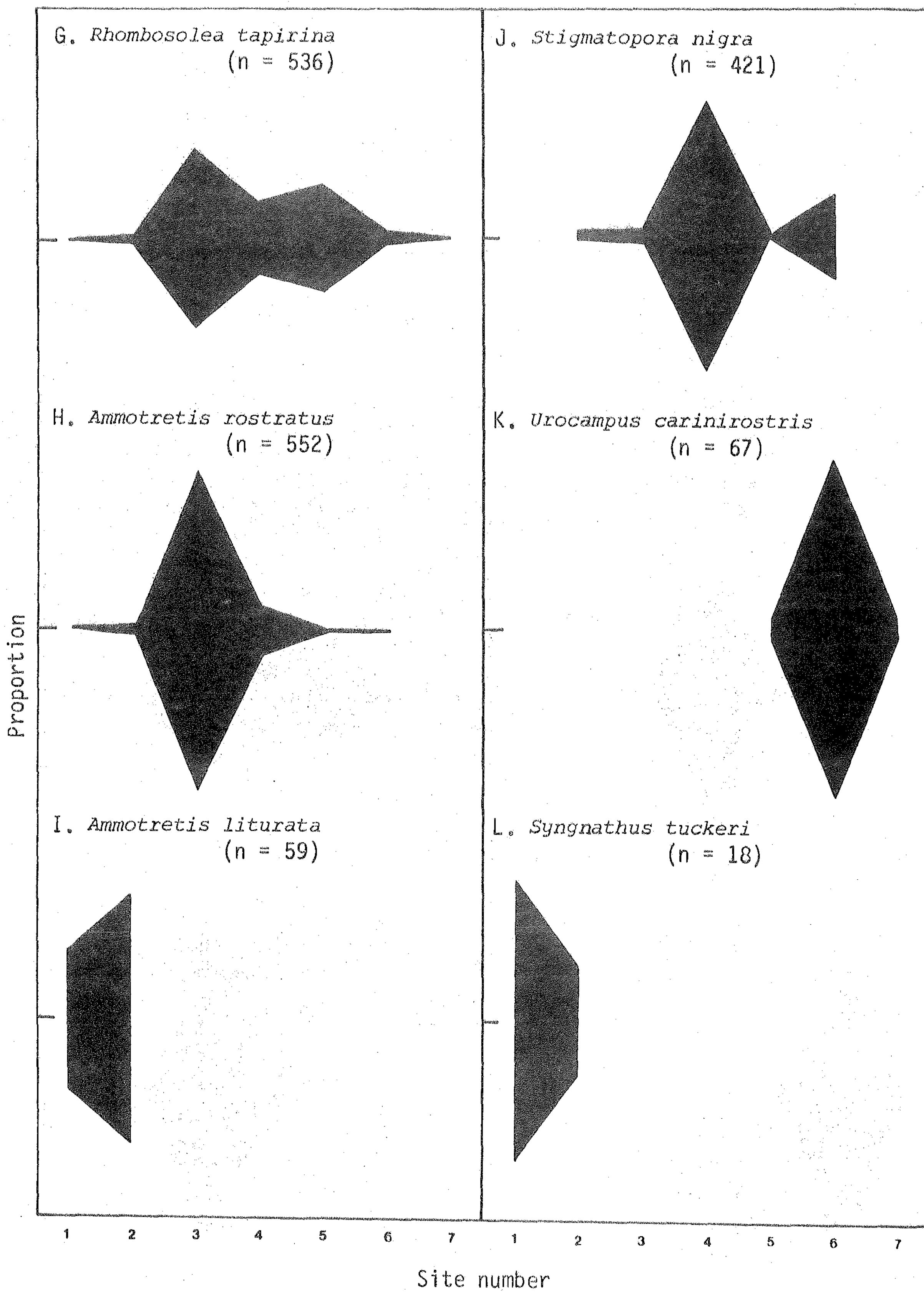
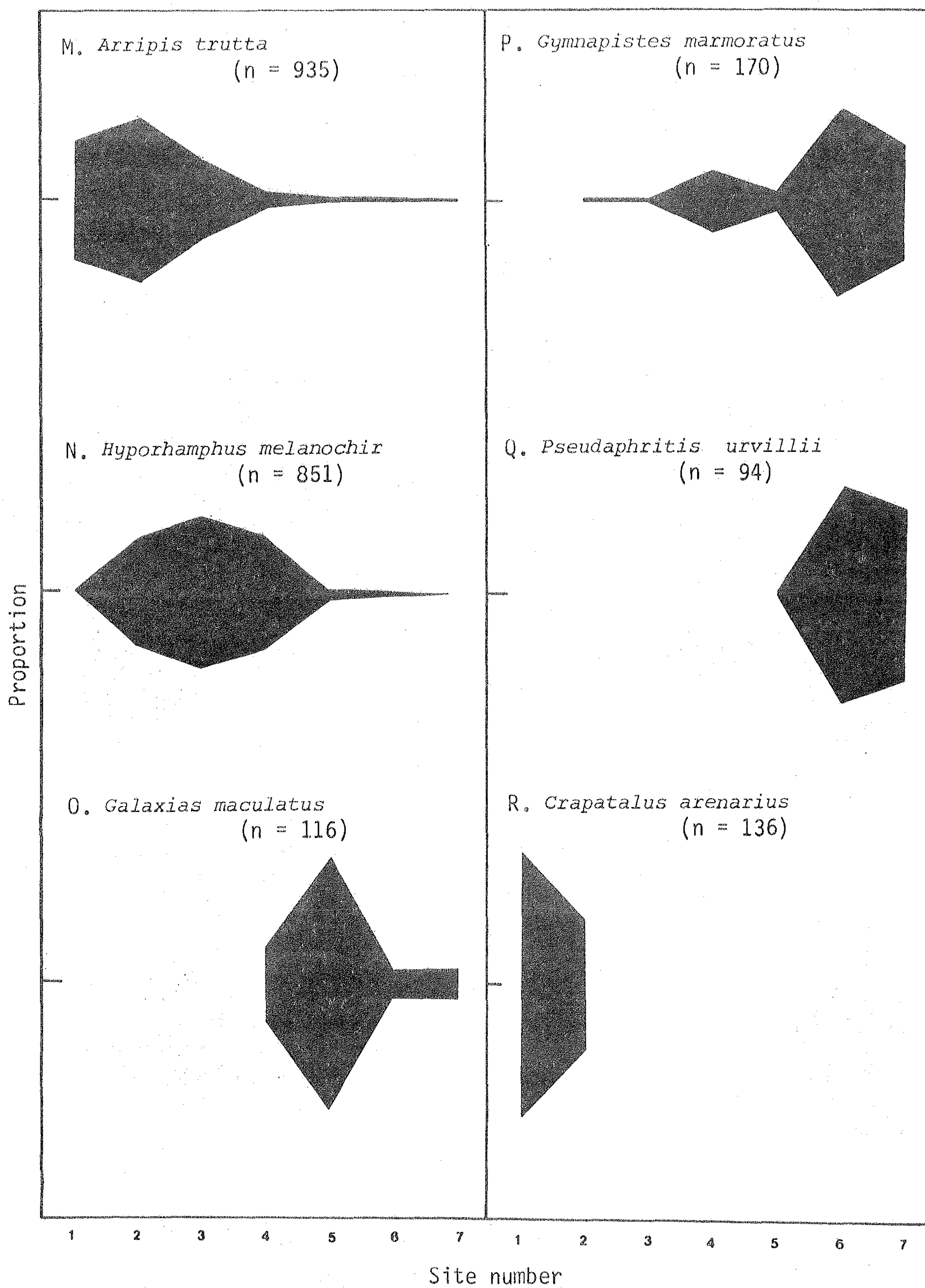

G. *Rhombosolea tapirina*
(n = 536)
J. *Stigmatopora nigra*
(n = 421)
H. *Ammotretis rostratus*
(n = 552)
K. *Urocampus carinirostris*
(n = 67)
I. *Ammotretis liturata*
(n = 59)
L. *Syngnathus tuckeri*
(n = 18)
Proportion
1
2
3
4
5
6
7
1
2
3
4
5
6
7
Site number

Fig. 6:11. Relative abundances of an arripid (M), a hemiramphid (N), a galaxiid (O), a scorpaenid (P), a bovichthyid (Q) and a leptoscopid (R) at the 7 sampling sites. Data is expressed as a proportion of the total number of indiviudals sampled (n).


M. *Arripis trutta*
(n = 935)
N. *Hyporhamphus melanochir*
(n = 851)
O. *Galaxias maculatus*
(n = 116)
P. *Gymnapistes marmoratus*
(n = 170)
Q. *Pseudaphritis urvillii*
(n = 94)
R. *Crapatalus arenarius*
(n = 136)
Proportion
1 2 3 4 5 6 7 1 2 3 4 5 6 7
Site number

The abundances of members of some benthic groups, in particular the families Leptoscopidae, Pleuronectidae, Gobiidae and Syngnathidae, were also high. The leptoscopid, *Crapatalus arenarius,* and a flounder, *Ammotretis liturata,* were also common at the beach sites whereas other pleuronectid species, *Ammotretis rostratus* and *Rhombosolea tapirina,* were abundant at some lower and middle estuarine sites. The goby, *Favonigobius tamarensis,* was most abundant in the lower and middle estuary and *Pseudogobius olorum* was more common in the upper estuary. Similarly, the pipefish, *Stigmatopora nigra,* was more abundant at vegetated sites in the lower and middle estuary (sites 4 and 6) but it was replaced at site 7 by another pipefish, *Urocampus carinirostris.*

The numerical distributions of these species from day samples, expressed in proportions by sites, are given in Figures 6:9 - 11.

6:5:3 Diel Characteristics

Forty-three species were collected in this section of the study; 36 from day and 35 from night samples (Appendix 6:1). The numbers of species did not differ significantly between day and night but differed with sampling position (Table 6:3c). The number of species was highest in the lower estuary (site 4) and lowest on the beach (site 2); this trend supports the findings from the previous year (see Section 6:5:1). There was insufficient evidence of a diel x site interaction.

The total number of individuals collected was 11,582; 8,373 from day and 3,209 from night samples. Abundances at all sites were higher at day than night (see Table 6:1) but these were not significantly different overall (Table 6:3d). The size of these site values, which were based on only 4 replicates, were determined by the number of atherinids, *Atherinosoma microstoma* and *A. presbyteroides;* numbers of these species were not significantly higher at day than night (Table 6:3e). Abundances, with these species removed, were only marginally different and these were not significant (Table 6:3f).

Other species which appeared to be more abundant in day samples included *Stigmatopora nigra*, *Aldrichetta forsteri* and *Contusus richei*, whereas *Anguilla australis* and *Hyporhamphus melanochir* were more abundant at night.

6:5:4 Dominant Species

Community score ratios (C.S.R.) were calculated for species from the 3 site groups obtained from cluster analysis (see Fig. 6:8), using only data from day samples.

The dominant and sub-dominant species from the beach sites (Table 6:4) agreed closely with occurrence and abundance information from both sampling areas. *Crapatalus arenarius* and *Arripis trutta* were indicator species.

The lower estuary (sites 3 and 4) possessed 6 species as dominant, 3 as sub-dominant and 1 as secondary (Table 6:5). In this situation, dominants were less obvious from raw abundance and occurrence data and this example showed the benefit of agglomerative techniques of this nature. The C.S.R.'s of indicator species, *Nesogobius* sp. 2 and *Ammotretis rostratus*, were largely attributed to their high fidelities to this region of the estuary (see Figs. 6:9, 10).

The middle and upper estuary (sites 5 - 7) had 6 species as dominant, 1 as sub-dominant and 2 as secondary (Table 6:6). The indicator species were *Atherinosoma microstoma* and *Pseudaphritis urvillii*. The latter, although poorly represented in abundance and occurrence rankings, had a

Table 6:4. Major species at beach stations (sites 1 and 2). Dominant species have community score ratios (C.S.R) $>$ 0.25 (in italics); sub-dominant species have C.S.R.'s $<$ 0.25 (normal type). Secondary species: *Syngnathus tuckeri, Ammotretis liturata*.

Species	Occurrence No.	%	Bio-index value	Fidelity	Community Score	Community Score Ratio
Crapatalus arenarius	23	88	91	1.00	179.0	0.90
Arripis trutta	19	73	93	0.48	79.6	0.40
Aldrichetta forsteri	14	54	88	0.23	32.6	0.16

Table 6:5. Major species in lower estuary (sites 3 and 4). Dominant species have community score ratios (C.S.R.) $>$ 0.25 (in italics); sub-dominant species have C.S.R.'s $<$ 0.25 (normal type). Secondary species: *Hyporhamphus melanochir*.

Species	Occurrence No.	%	Bio-index value	Fidelity	Community Score	Community Score Ratio
Aldrichetta forsteri	22	85	79	0.37	60.7	0.30
Rhombosolea tapirina	22	85	62	0.49	72.0	0.36
Nesogobius sp. 2	21	81	67	0.84	124.3	0.62
Atherinosoma presbyteroides	20	77	80	0.51	80.1	0.40
Ammotretis rostratus	20	77	62	0.70	97.3	0.49
Arripis trutta	15	58	56	0.38	43.3	0.22
Stigmatopora nigra	15	58	55	0.52	58.8	0.29
Favonigobius tamarensis	14	54	57	0.40	44.4	0.22
Atherinosoma microstoma	13	50	65	0.31	35.7	0.18

Table 6:6. Major species in middle and upper estuary (sites 5 - 7). Dominant species have community score ratios (C.S.R.) > 0.25 (in italics); sub-dominant species have C.S.R.'s < 0.25 (normal type). Secondary species: *Urocampus carinirostris, Gymnapistes marmoratus.*

Species	Occurrence No	%	Bio-index value	Fidelity	Community Score	Community Score Ratio
Atherinosoma microstoma	39	100	100	0.62	124.0	0.62
Aldrichetta forsteri	36	92	90	0.40	72.8	0.36
Favonigobius tamarensis	31	79	79	0.60	94.8	0.47
Atherinosoma presbyteroides	26	67	82	0.44	65.6	0.33
Rhombosolea tapirina	22	56	69	0.32	40.0	0.20
Pseudogobius olorum	20	51	67	0.77	90.9	0.45
Pseudaphritis urvillii	19	49	68	1.00	117.0	0.59

fidelity value of 1.0. Once again this exhibited the importance of fidelity in determining the dominance of species in communities.

All indicator species had distributions centred in areas where they were most common but, only *Crapatalus arenarius* and *Pseudaphritis urvillii* were restricted to one group of sites. Of the 7 widespread species isolated in Section 4, *Arripis trutta, Nesogobius* sp. 2, *Ammotretis rostratus* and *Atherinosoma microstoma* were identified as indicators and *Rhombosolea tapirina, Aldrichetta forsteri* and *Atherinosoma presbyteroides* were identified as dominants. Ubiquitous species are characteristically tolerant of conditions offered by a wide range of habitat types and should not be used to characterise any one community even though they may be visually dominant (Grange, 1979). Similarly, "if two groups have very similar ranks of dominant and sub-dominant species they probably represent different facies of the one community rather than two separate communities" (Grange, 1979).

Aldrichetta forsteri, Atherinosoma presbyteroides and *Rhombosolea tapirina* were dominants in both estuarine groups. Following Grange's arguments, the two estuary groups would represent only a single community type. However, the presence of high fidelity species in each group, supported by earlier evidence (see Sections 4:4 and 6:5:1), suggested that two assemblages existed within the estuary: a sheltered bay marine fauna in the lower estuary and an estuarine fauna in the middle and upper estuary. Consequently under certain conditions, high fidelity secondary species, rather than dominants, could be better indicators of community types.

This analysis isolated 17 species and, notably, these comprised 98.7% of the total number of individuals sampled. These species were considered to have the greatest 'importance value' and aspects of their ecology are treated in later sections.

6:6 HABITAT USAGE

Factors affecting the behaviour and distribution of fish include salinity, temperature, oxygen concentration, current velocity, suspended solids, types of vegetation and bottom sediments, and various pollutants (Lenanton, 1977). Hence, the way in which these factors are represented in an environment, such as as estuary, may ultimately determine the faunal composition of that environment. Similarly, these factors also influence the way in which the environment is used by the species. This so-called 'estuarine usage' (Lenanton, 1977) relates to aspects of

Species	No. of individuals sampled	Size class range (mm)	Proportion of adults (%)	Approximate Length of First Maturity (L.F.M.)(mm) M	F	Sex Ratio: No. inspected	No. sexed	M:F	Spawning Information: Period	Locality	Smallest individuals collected	Maximum G.S.I. (%) M	F	Preferred Habitat: Spatial	Substrate	Locality	Salinity range (‰)	Temp. range (°C)
Hyporhamphus melanochir	953	60-300	0.8	245	(Thomson, 1957)	285	249	1:2.15***	Summer	Marine (?)	Sept.	N	N	P	Sand	Estuary	23.3-34.8	10.5-26.4
Atherinosoma microstoma	21515	10-100	99.9	20	20	1432	1265	1:2.18***	Aug.-Jan.	Estuary (upper?)	Jan. Mar. Apr. May	6.4	16.0	B.P.	Brackish weed & seagrass	Middle & upper estuary	0.5-34.3	6.0-27.7
Atherinosoma presbyteroides	13933	10-100	65.6	50	50	1301	1149	1:1.87***	Sept.-Feb.	Estuary (lower?)	Apr. May	14.3	20.2	B.P.	Sand & seagrass	Lower estuary	1.0-35.0	6.0-27.7
Urocampus carinirostris	83	45-105	94.7	N	60	76	76	1:1.92***	Nov.-Jan.	Estuary (middle & upper)	Jan.	N	14.3	B_V	Brackish weed & seagrass	Middle & upper estuary	0.5-34.6	7.8-24.4
Syngnathus tuckeri	18	70-190	27.8	N	150?	18	18	1:1	Early Summer?	Marine (?)	Feb.	N	8.1	B_V	Marine algae	Beach	33.8-33.9	9.6-20.2
Stigmatopora nigra	917	25-140	70.7	N	100	468	462	1:1.30***	Jan.-Feb.	Estuary (lower & middle)	Jun.	N	12.5	B_V	Seagrass	Lower & middle estuary	5.8-34.8	6.0-23.1
Gymnapistes marmoratus	240	30-185	54.5	80	80	202	188	1:1.02	Sept. - Oct.	Estuary (mouth)	Nov.	13.0	19.2	B	Sand & seagrass	Upper estuary	0.5-34.0	6.8-23.1
Arripis trutta	1247	40-210	0	390	(Stanley & Malcom, 1977)	569	16	1:1.30	Late spring-early summer?	Marine (?)	Apr.	N	N	B.P.	Sand	Beach	18.6-35.0	6.8-20.6
Aldrichetta forsteri	5409	20-370	0.4	220	(Thomson, 1957)	1379	154	1:0.81*	Spring?	Marine (?)	Mar. Apr. May	N	N	B.P.	No clear preference	Middle estuary	0.5-34.8	6.0-27.7
Crapatalus arenarius	198	30-115	69.3	50	60	205	183	1:0.79*	Dec. - Feb.	Marine (beach)	Feb.	2.0	6.3	B_B	Sand	Beach	18.6-35.0	8.0-20.6
Pseudaphritis urvillii	197	25-230	45.1	N	150	175	143	1:12.00***	Sept.-Oct.	Estuary (lower & middle?)	Jan.	N	21.7	B	Sand & seagrass	Lower & middle estuary	0.5-30.4	6.1-27.7
Favonigobius tamarensis	930	15-90	97.4	30	30	621	607	1:1.67***	Nov.-Feb.	Estuary (lower & middle)	Mar.	N	22.7	B	Sand & seagrass	Lower & middle estuary	0.5-34.6	6.0-27.7

Species	No. of individuals sampled	Size class. range (mm)	Proportion of adults (%)	Approximate Length of First Maturity (L.F.M.) (mm) M	F	Sex Ratio No. inspected	No. sexed	M:F	Spawning Information Period	Locality	Smallest individuals collected	Maximum G.S.I. (%) M	F	Preferred Habitat Spatial	Substrate	Locality	Salinity range (‰)	Temp. range (°C)
Nesogobius sp.2	519	20-90	73.1	30	50	359	345	1:1.35***	Sept.-Feb.	Estuary (lower)	Mar. Apr.	7.9	17.9	B	Sand	Lower estuary	1.0-34.8	6.0-23.5
Pseudogobius olorum	126	15-45	95.0	20	30	121	118	1:1.07	Nov.-Feb.	Estuary (upper)	Feb.	5.9	19.0	B_B	Mud & brackish weed	Upper estuary	0.5-31.9	6.0-27.7
Ammotretis rostratus	677	10-310	0.1	200 (Lenanton, 1977)		367	39	1:2.90***	Continuous (mainly early spring)	Marine (offshore)	Oct. Nov.	N	N	B_B	Sand	Lower estuary	1.0-35.0	6.8-23.0
Ammotretis liturata	69	40-310	1.4	(170 < LMF < 310)		69	28	1:0.87	Late winter-early spring?	Marine (offshore?)	Dec.	N	N	B_B	Sand	Beach	24.8-35.0	8.0-20.6
Rhombosolea tapirina	620	10-330	3.8	N	200	473	136	1:4.91***	Continuous (mainly early spring)	Marine (offshore and estuary?)	Sept.	N	13.3	B_B	Sand	Lower estuary	0.5-35.0	6.0-26.4

Table 6:7. Summary of preferred habitat and spawning information for the 17 major species occurring in the environs of the Great Swanport Estuary.

Significance levels for sex ratios were determined from a chi-square analysis. M, males F, females. N, insufficient data.

P, pelagic. B.P., benthopelagic, B, benthic. B_V, benthic amongst vegetation. B_B, benthic burrower.

reproduction, feeding and age group occupation of the species. Similar patterns of use are equally applicable to beach faunas, hence the general regime is referred to collectively as 'habitat usage'.

Patterns of beach and estuarine usage are considered mainly for the 17 major species identified in Section 6:5:4 but, where relevant, comments are made on other species found in the environs of this estuary.

6:6:1 Reproduction and Growth

Spawning Ground

In situations whereby individuals of a species are restricted to a habitat throughout their life cycle, the ability to reproduce in that habitat is of prime importance. Ten of the 17 major species provided evidence of spawning within the estuary (Table 6:7). *Atherinosoma microstoma, Pseudogobius olorum* and *Urocampus carinirostris* probably spawned in the upper and middle estuary, while *Stigmatopora nigra, Pseudaphritis urvillii, Nesogobius* sp. 2, *Gymnapistes marmoratus, Atherinosoma presbyteroides, Favonigobius tamarensis* and *Rhombosolea tapirina* were found in spawning condition in the lower areas of the estuary.

Thomson (1957b) found that at least 8 of the 19 most common fishes of some West Australian estuaries matured in estuaries. Bell (1980) accredited only 4 of 14 commercial species from Botany Bay as being estuarine spawners; 7 of the remaining 10 species were believed to spawn in nearby marine areas close to the bay entrance.

Resident species were more restricted in their distributions and certainly used the estuary as a spawning ground. Some, such as *Nesogobius* sp. 2, *Stigmatopora nigra* and *Gymnapistes marmoratus*, were also residents and seasonal residents of sheltered beaches (see Section 4:4). Grant (1971) suggested that the breeding population of *Gymnapistes marmoratus* in D'Entrecasteaux Channel migrated into the shallow waters of bays to spawn. Other species, such as *Rhombosolea tapirina*, which have been suspected of spawning in estuaries (Kurth, 1954), also appear to spawn in deeper areas of marine bays (Crawford, personal communication). Consequently, marine species that reach spawning condition in the lower, euhaline areas of the estuaries are probably capable of spawning in additional marine habitats. Wallace (1975b) and Lenanton (1977) discussed this concept and hypothesised that most species use the stability of the marine environment to assist the survival of eggs and larvae.

Such facultative behaviour is not applicable to all estuary-dwellers because some species are restricted to estuaries (Day *et al.*, 1981) and spawning in these habitats is obligatory. Few species occurring in the present study area appear to fit this category.

Some members of the families Atherinidae and Gobiidae are adapted for reproducing in estuaries and possess adhesive threads for the attachment of eggs to seagrasses and the underside of rocks (Lenanton, 1977). The species referred to by Lenanton are either ecologically matching congenerics or are conspecific with species collected in the Great Swanport Estuary. Thus, their reproductive strategies are likely to be at least similar.

Quantitative sampling did not provide sufficient numbers of black bream, *Acanthopagrus butcheri*, for the spawning site to be adequately determined. However, during the period of gonad ripeness (November - January), large individuals caught by lining and gill netting were most abundant in the lower and middle estuary. The spawning grounds in South Australian waters were assumed to be in estuaries near the marine-freshwater interface. Weng (1971) and Lenanton (1977) have provided convincing evidence that the species lives and breeds entirely within estuaries.

Mature gonads from a few individuals of *Pseudaphritis urvillii* suggested that spawning may occur in the lower and middle areas of estuaries. Hortle (1978) provided evidence of a downstream movement of *P. urvillii* during the breeding season but could not locate a breeding site.

Of the marine spawners, only *Crapatalus arenarius* spawned in the beach habitat. The problems associated with fertilizing eggs in turbulent environments were partly overcome by internal fertilization through an intromittent organ.

Few adult *Aldrichetta forsteri* were recorded from this estuary and, although Lenanton (1977) recorded ripe adults from estuaries, he hypothesised that spawning takes place in sheltered marine bays. The weedy parts of sheltered bays may also be important spawning areas for *Hyporhamphus melanochir* (Ling, 1958).

The breeding grounds of some other species were even further afield. *Ammotretis rostratus* appears to spawn offshore (Crawford, personal communication), whereas *Arripis trutta* spawns outside Tasmanian waters (Stanley and Malcolm, 1977).

Spawning and maturation areas of many minor species were difficult to determine because of the unavailability of replicates, although 4 species, *Galaxias maculatus, Tasmanogobius lordi, T.* sp. 3 and *Cristiceps australis,* were collected in the estuary with mature or ripe gonads. *Galaxias maculatus* is basically a freshwater species that migrates into estuaries to spawn (Fulton, 1979; McDowall, 1980b). In comparison, little is known of *T. lordi* (Hoese and Larson, 1980) or of its congener, *T.* sp. 3. *T. lordi* is a burrowing species which normally inhabits streams and oligohaline estuaries. *T.* sp. 3 is mainly resident in meso- and polyhaline regions of estuaries which in this system is the upper estuary. Both species were found in spawning condition in the middle and lower estuary. The weedfish, *C. australis,* is a viviparous species and is probably capable of reproducing in any habitat where the adults are abundant.

Information on the spawning areas of some other species is available in the literature. A goby, *Favonigobius lateralis*, has been shown to spawn in estuaries (Lenanton, 1977). Two leatherjackets, *Meuschenia freycineti* and *Acanthaluteres spilomelanurus*, spawn in marine habitats (Last, 1975) but they may also spawn in this estuary.

Reports of other species spawning outside estuaries are as follows: *Urolophus paucimaculatus* (Edwards, 1980), *Pseudophycis bachus* (Walker, 1970), *Platycephalus bassensis* (Anonymous, 1973), *Sillago bassensis* (Wilson, personal communication)and *Contusus richei* (Habib, 1979) spawn in bays; *Girella tricuspidata* (Bell, 1980) and *Penicipelta vittiger* (Last, 1975) in shallow coastal marine areas; *Caranx georgianus* (Bell, 1980), *Anguilla australis* (McDowall and Beumer, 1980) and *A. reinhardtii* (Beumer, 1981) in offshore areas; and *Mordacia mordax* (Strahan, 1980a) in freshwater areas.

The spawning area of *Mugil cephalus* has been open to conflicting viewpoints but evidence provided by Grant and Spain (1975) suggests that the species spawns inshore, in shallow tropical areas. Consequently, spawning in Tasmanian waters is unlikely.

Spawning Period and Juvenile Recruitment

The main spawning period for the major species ranged from August through to February (see Table 6:7), with most species having peaks in late spring and early summer. Of the minor species that spawned in the estuary, at least *Galaxias maculatus* was a winter spawner. Only one of the 15 more abundant species studies by Lenanton (1977) spawned during winter.

Bell (1980) classified species into three broad spawning categories based on peak spawning period: winter/spring; summer/autumn; and summer and autumn spawners. Most of the species studied peaked in summer/autumn although several spawned during the spring/winter period.

Several species, such as *Atherinosoma microstoma, A. presbyteroides, Nesogobius* sp. 2, *Favonigobius tamarensis* and *Pseudogobius olorum,* had extended spawning periods lasting several months. Lenanton (1977) observed similar durations for *F. tamarensis* and *P. olorum* in West Australian estuaries although the period commenced and terminated a month earlier. Two *Atherinosoma* species, *A. rockinghamensis* and *A. edelensis*, were only observed in spawning condition in September, but a lengthy period of larval occurrence suggests that these species also have prolonged spawning periods. Extended spawning periods in estuarine fish have been viewed as an adaptation to ensure that juvenile fishes can utilize the period of most favourable conditions for larval survival (Wallace, 1975b).

Mature and ripe individuals of *Galaxias maculatus* were collected from the middle and upper estuary from July to September. Although McDowall (1968; 80b) stated that the species spawns in autumn, Benzie (1968) noted lunar phases which were capable of initiating spawning throughout most of the year. Scott (1938) observed a return of adult *G. maculatus* to upstream areas in July which added evidence to an early winter spawning. A landlocked population in Victoria spawned in winter-early spring (Pollard, 1971).

Rhombosolea tapirina is a continuous spawner (Kurth, 1954), however a great influx of juveniles into the estuary in August and September clearly corresponded with a spawning peak in late winter-early spring. The continuous appearance of small juveniles throughout the year indicated that this strategy was likewise adopted by *Ammotretis rostratus*.

The influx of juveniles into an estuary is largely dependent on the spawning time and place, mobility of larvae and juveniles and dispersive potential of the system. Earliest arrival time of juveniles of the major species are given in Table 6:7 but this information is largely incomplete. Variable ages of these species also limited the usefulness of the data, however a general trend of juveniles first occurring in the estuary during summer and autumn was noticeable. This trend is in accordance with spawning period patterns and may be associated with a strategy to utilize the estuary at a time of greatest hydrological stability. Several non-resident species were found in the estuary during this period and many of these were juveniles of marine species which inhabit reef habitats as adults. Typical examples were *Genypterus* sp., *Scorpaena ergastulorum, Dotalabrus aurantiacus, Heteroclinus adelaidae,Nesogobius pulchellus* and *Penicipelta vittiger.*

Growth Stage and Size Distribution

The approximate lengths of first maturity (L.F.M.) for major species were determined where possible and the proportion of adults sampled was tabulated (see Table 6:7).

Only one species, *Arripis trutta,* was never collected as an adult in this study, whereas 11 species were frequently represented by both adults and juveniles. *Aldrichetta forsteri* and *Hyporhamphus melanochir* and all the pleuronectid species were also rarely collected as adults. In comparison, smaller resident species such as the gobiids and atherinids were most abundant as adults. These figures were probably biased towards adults for small manoeuverable species such as *Pseudogobius olorum* where escapement through the net by juveniles may have been an important variable.

The overall compositional characteristics of the minor species resembled those above. All species were classified, based on their maximum known size (L_{max}) into one of five groups (Table 6:8). The adult/ juvenile status of species was estimated from reproductive data and

Table 6:8. Size classes of fishes occurring in the Great Swanport Estuary and environs based on maximum attainable total length (L_{max}). This measurement is based on literature records and other unpublished data. Size ranges and growth stages of individuals caught in this study are given. J, juveniles; A, adults. The maximum size of *Myliobatis* is based on a width measurement, W.

(a) very small (less than 125 mm T.L.)

Species	L_{max} (mm)	Author/Source	Size Range (mm)	Growth Stage Estuary	Growth Stage Beach
Spratelloides robustus	100	Scott, Glover & Southcott (1974)	55	A?	
Atherinosoma microstoma	90	Ivantsoff (1980)	10-100	J/A	A
Atherinosoma presbyteroides	95	Scott *et al.* (1974)	10-100	J/A	J/A
Atherinason sp.	90	T.F.D.A. collections	70	A	
Urocampus carinirostris	100	Scott *et al.*,(1974)	45-105	J/A	A
Crapatalus arenarius	90	Scott *et al.* (1974)	30-115		J/A
Heteroclinus adelaidae	76	Hoese (1976)	35	A?	
Favonigobius tamarensis	110	Hoese & Larson (1980)	15-90	J/A	
Favonigobius lateralis	90	Scott *et al.* (1974)	45-50	A	
Nesogobius hinsbyi	70	T.F.D.A. collections	45	A?	
Nesogobius pulchellus	60	T.F.D.A. collections	45	A	
Nesogobius sp. 2	90	Scott *et al.* (1974)	20-90	J/A	
Pseudogobius olorum	50	Hoese & Larson (1980)	15-45	J/A	
Tasmanogobius lordi	35	Hoese & Larson (1980)	30-35	J/A	
Tasmanogobius sp. 3	50	T.F.D.A. collections	20-50	J/A	
Brachaluteres jacksonianus	89	Scott *et al.* (1974)	25-40	J/A	

(b) small (126 - 250 mm T.L.)

Species	Lmax (mm)	Author/Source	Size Range (mm)	Growth Stage Estuary	Growth Stage Beach
Engraulis australis	150	Scott *et al.* (1974)	55-95	J/A	J/A
Galaxias truttaceus	200	McDowall (1980b)	40-60	J	
Galaxias maculatus	190	McDowall (1980b)	35-115	J/A	
Syngnathus tuckeri	130	Munro (1958)	70-190		J/A
Stigmatopora nigra	130	Scott *et al.*(1974)	25-140	J/A	J/A
Stigmatopora argus	250	Scott *et al.*(1974)	120	A?	
Gymnapistes marmoratus	229	Grant (1971)	30-185	J/A	A
Paratrigla papilio	180	Scott *et al.*(1974)	40	J	
Dotalabrus aurantiacus	200	Scott *et al.*(1974)	35	J	
Neoodax balteatus	122	Scott (1976)	25-140	J/A	
Cristiceps australis	230	Scott (1976)	30-165	J/A	J/A
Pictiblennius tasmanianus	130	Scott (1976)	35-55	J	
Acanthaluteres spilomelanurus	150	Richardson (1846)	35-100	J/A	
Contusus richei	200	Hardy (1981)	20-70	J	J

(c) medium (251 - 500 mm T.L.)

Species	Lmax (mm)	Author/Source	Size Range (mm)	Growth Stage Est-uary	Growth Stage Beach
Mordacia mordax	480	Strahan (1980a)	340	A	
Scorpaena ergastulorum	380	Scott *et al.*(1974)	25-50	J	
Platycephalus bassensis	410	Scott *et al.*(1974)	45-360	J/A	J/A
Sillago bassensis	330	Scott *et al.*(1974)	45-95		J
Aldrichetta forsteri	400	Scott *et al.*(1974)	20-370	J/A	J/A
Pseudaphritis urvillii	360	Scott *et al.*(1974)	25-230	J/A	
Ammotretis rostratus	250	Scott *et al.*(1974)	10-310	J/A	J
Ammotretis liturata	230	Scott *et al.*(1974)	40-310		J/A
Rhombosolea tapirina	360	Scott *et al.*(1974)	10-330	J/A	J
Penicipelta vittiger	305	Scott *et al.*(1974)	25-65	J	
Meuschenia freycineti	457	Scott *et al* (1974)	15-340	J/A	
Contusus sp.	254	Scott *et al.*(1974)	125	A?	

(d) Large (501 - 1000 mm T.L.)

Species	Lmax (mm)	Author/Source	Size Range (mm)	Growth Stage Est-uary	Growth Stage Beach
Urolophus paucimaculatus	560	Edwards (1980)	360	A	
Anguilla australis	900	McDowall & Beumer (1980)	55-430	J	
Pseudophycis bachus	625	Walker (1970)	105-150	J	J
Genypterus sp.	910	Scott *et al.*(1974)	95	J	
Hyporhamphus melanochir	510	Scott *et al.*(1974)	60-300	J/A	J/A
Caranx georgianus	760	Scott *et al.*(1974)	50-135	J	J
Arripis trutta	910	Scott *et al.*(1974)	40-210	J	J
Acanthopagrus butcheri	600	Scott *et al.*(1974)	55-340	J/A	A
Girella tricuspidata	510	Scott *et al.*(1974)	25	J	
Mugil cephalus	760	Scott *et al.*(1974)	135		J

e) Very large (greater than 1000 mm T.L.)

Species	Lmax (mm)	Author/Source	Size Range (mm)	Growth Stage Est-uary	Growth Stage Beach
Myliobatis australis	(W)1200	Scott *et al.*(1974)	(W)900	A	
Salmo trutta	1400	McDowall & Tilzey (1980)	195	J	

Table 6:9. : Size composition of beach and estuarine fishes based on maximum adult size and their occurrences as adults (A) and juveniles (J). n_B, n_E and N are beach, estuary and combined totals respectively.

		Maximum adult length, T.L. (mm)					
		less than 125	125-250	251-500	501-1000	greater than 1000	total
Beach	J	0	1	3	4	0	8
	A	2	1	0	1	0	4
	J/A	2	4	3	1	0	10
	n_B	4	6	6	6	0	22
Estuary	J	0	5	2	6	1	14
	A	6	1	2	1	1	11
	J/A	9	7	6	2	0	24
	n_E	16	12	10	9	2	49
	N	17	13	12	10	2	54

information obtained from the literature.

The small fishes contained the greatest relative number of species present as adults in both beach and estuarine areas (Table 6:9). Also, a general reduction in the number of species with ascending size classes was evident for estuarine fishes but this trend was not apparent for the beach fishes.

Most of the larger species present as both adults and juveniles were major species and these occurred most freqeuntly as juveniles. The adult (A)/juveniles (J) occurence ratios of the remaining minor species, *Platycephalus bassensis* (A/J = 0.18) and *Meuschenia freycineti* (A/J = 0.34), were low while the estuarine species, *Acanthopagrus butcheri* (A/J = 0.85), was more often collected as an adult. Diving observations suggested that juveniles of *A. butcheri* were more abundant in the upper parts of the estuary where the salinities were oligohaline or freshwater.

Sex Ratio

Twelve major species exhibited significant differences ($P < 0.05$) in sex ratio (see Table 6:7). The most significant were *Hyporhamphus melanochir, Ahterinosoma microstoma, A. presbyteroides, Urocampus carinirostris, Stigmatopora nigra, Pseudaphritis urvillii, Favonigobius tamarensis, Nesogobius* sp. 2, *Ammotretis rostratus* and *Rhombosolea tapirina* and, in each case, females were more abundant than males.

Bell (1980) found that half of the 14 species he studied from Botany Bay exhibited differences in sex ratio ($P < 0.01$) and, in all but 2 cases, females were the more common sex. Furthermore, dramatic variations between the sex ratios for the whole population and for the adult populations of some species was found.

Hortle (unpublished data) found that females of *Pseudaphritis urvillii* were more abundant than males in riverine areas. A ratio of 1:12 obtained in the present study suggests than there could be a dominance of females in all areas of the species' distribution.

A sex ratio of 1:25 was observed for *Contusus richei* in a New Zealand estuary by Webb (1973a). Habib (1979) has demonstrated monthly fluctuations in the sexes of individuals from a harbour in New Zealand but his values averaged 1:1.4. Only a small number of gonads (n = 53) of *C. richei* were inspected during this study and the sex ratio was 1:1.65.

Nikolsky (1963) has stated that the observed sex ratio of the majority of species is close to unity. Hence, some authors have linked biased sex ratios to non-breeding populations (Webb, 1973a).

Selection of one sex over another may be of adaptive significance and the use of sex reversal by many fish tends to support this argument. This ratio can also be modified by differential zygote mortality depending on spatial and temporal characteristics (Baylis, 1981). Major estuarine residents such as *Atherinosoma microstoma*, *A. presbyteroides*, *Favonigobius tamarensis* and *Nesogobius* sp. 2 possessed sex ratios strongly biased towards females, but further studies of their reproductive behaviours are required before the reasons for these biases will be fully understood.

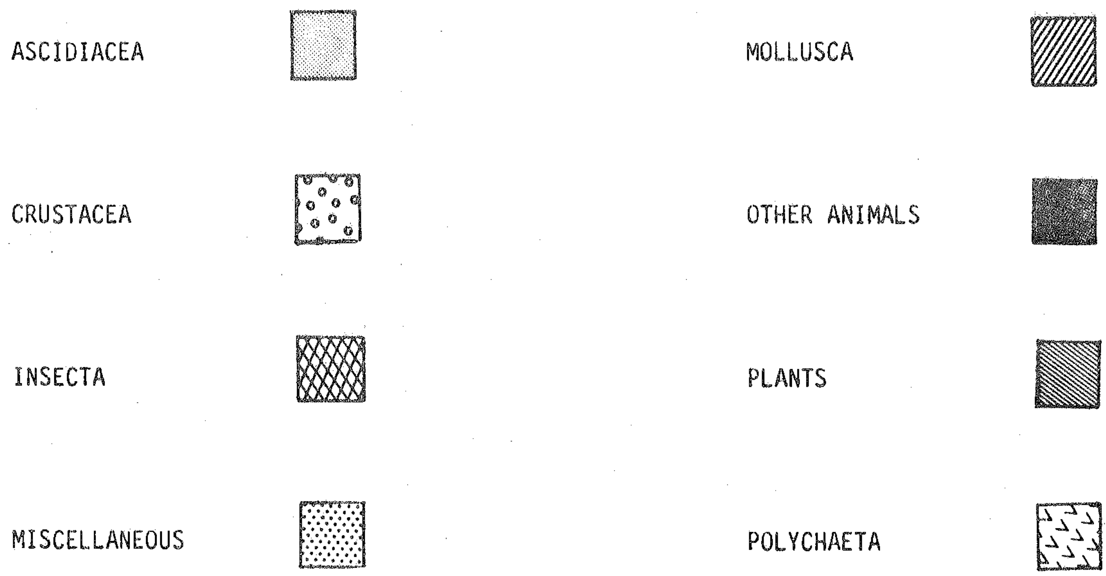
6:6:2 Food Habits

Community Components

Although the habitat types varied markedly between sampling sites, the major compositions of diets were similar (Figs. 6:12; 13a, b). Crustaceans were major food components at all sites during the day but polychaetes, insects, ascidians and molluscs were also important. The proportions of sediments and organic detritus ingested were also high at most sites.

Amphipods and copepods were the dominant crustacean components at all sites, however, the relative importance of these and other lower order taxa varied between sites (Fig. 6:14). Predominantly marine groups such

Fig. 6:12. : Key to prey groups from the following food charts (Figs. 6:13a,b; 6:14).



(A)	Amphipoda	(I)	Isopoda
(As)	Ascidiacea	(In)	Insecta
(C)	Copepoda	(M)	Mysidacea
(Ch)	Chlorophyta	(Mc)	Seagrasses
(Cl)	Cladocera	(P)	Polychaeta
(Cu)	Cumacea	(Rc)	Remainder - crustacea
(D)	Decapoda	(Rl)	Remainder - mollusca
(Dm)	Digested material	(Rm)	Remainder - miscellaneous
(Do)	Organic detritus	(Ro)	Remainder - other animals
(Ds)	Diatoms/Desmids)	(Rp)	Remainder - plants
(G)	Gastropoda	(Sd)	Sediment

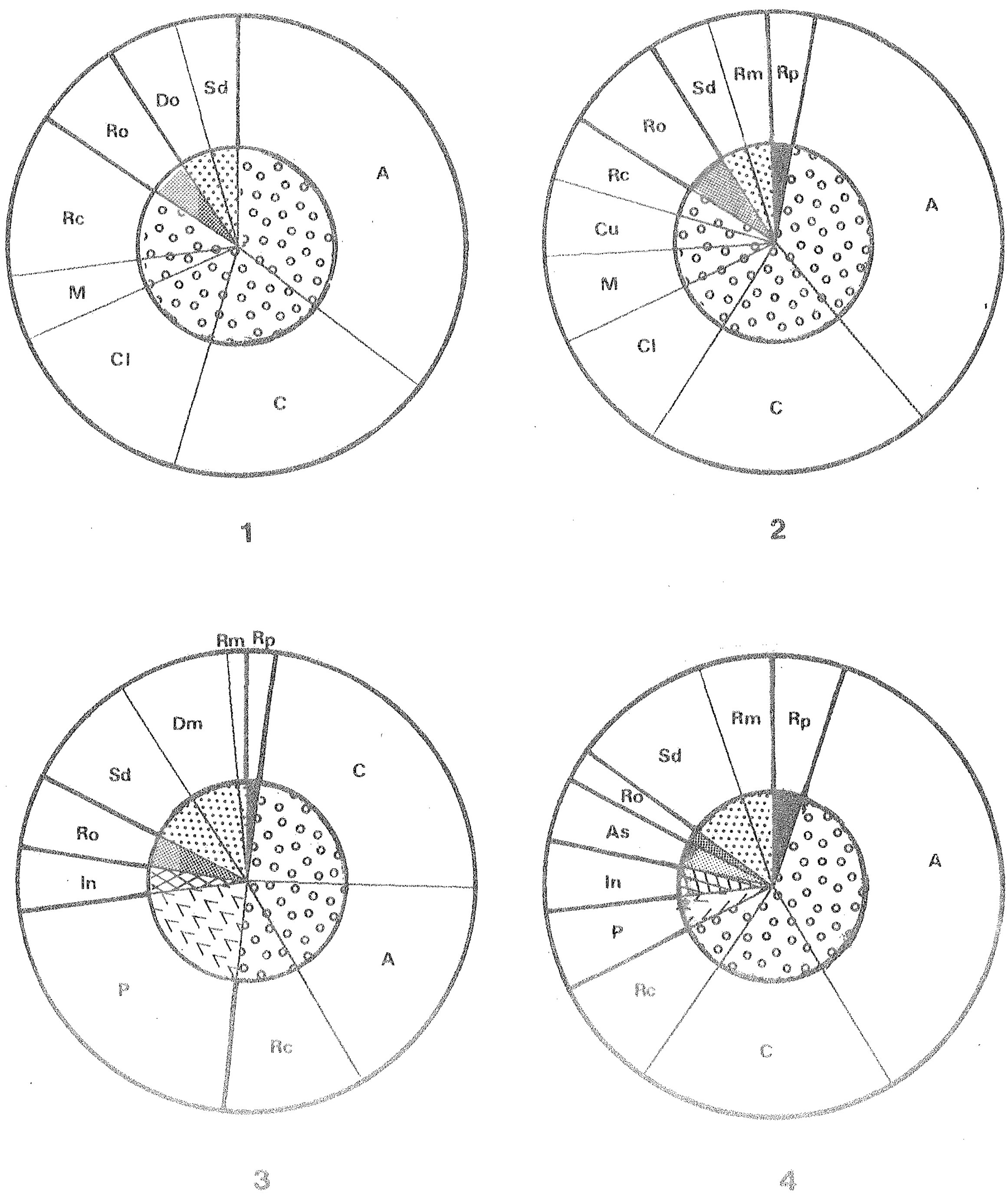
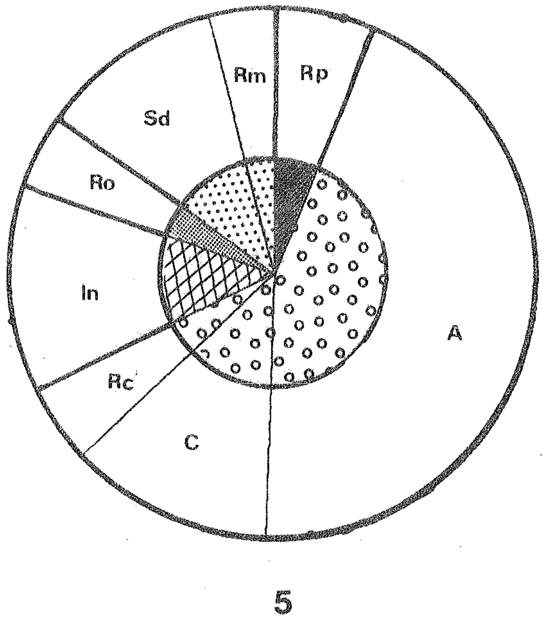
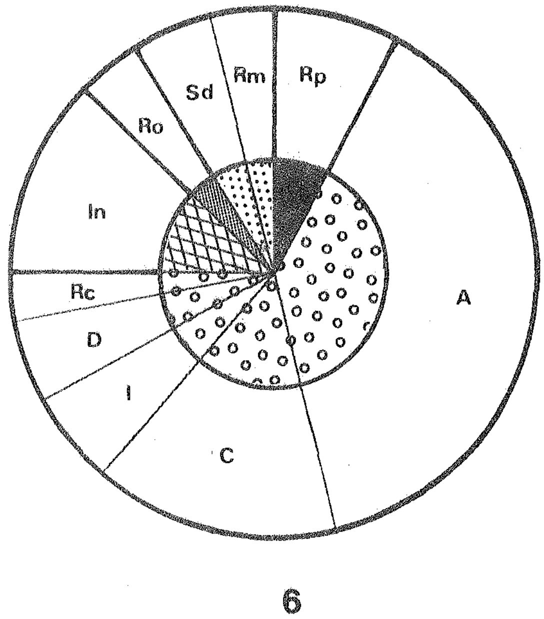


Fig. 6:13a : Proportions of prey groups forming the diets of fishes from sampling sites 1 - 4.





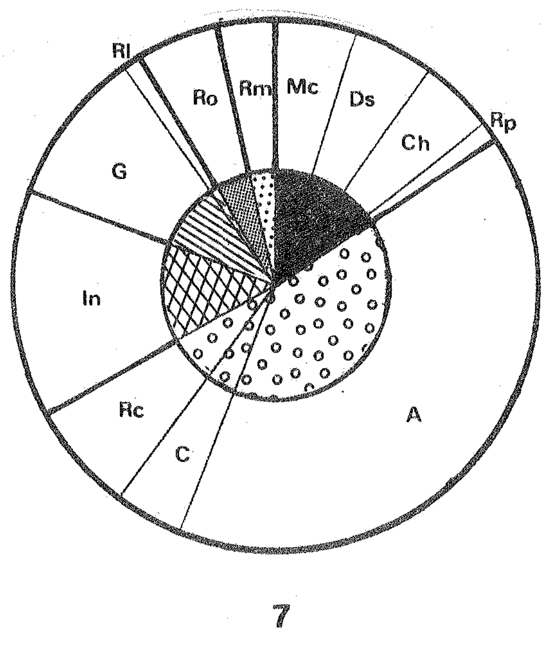


Fig. 6:13b: Proportions of prey groups forming the diets of fishes from sampling sites 5 - 7.

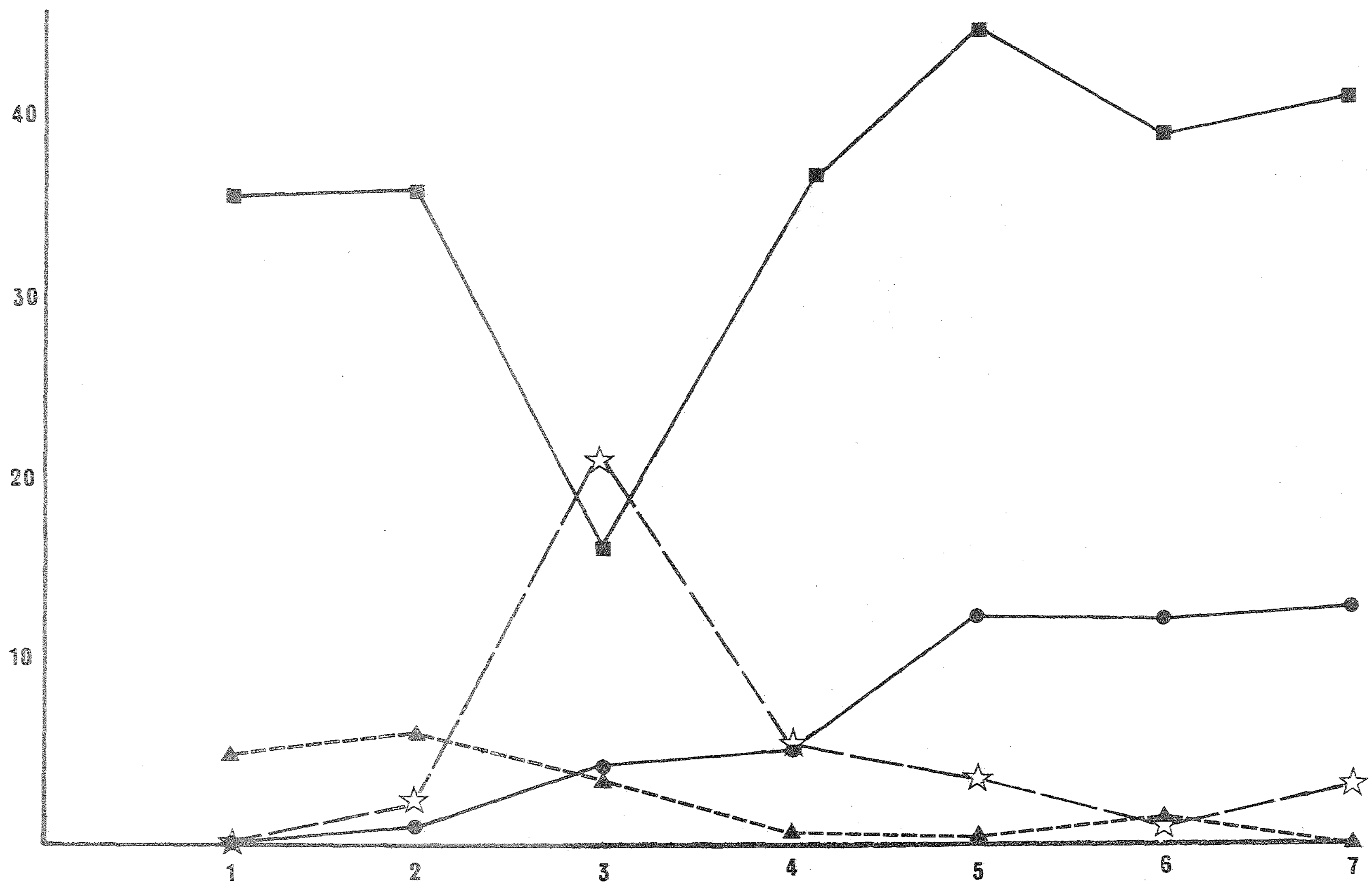


Fig. 6:14. Percentage contribution to the diets of fishes at each sampling site of 4 important prey groups: (■), amphipods; (☆), polychaetes; (●), insects; and (▲), mysids.

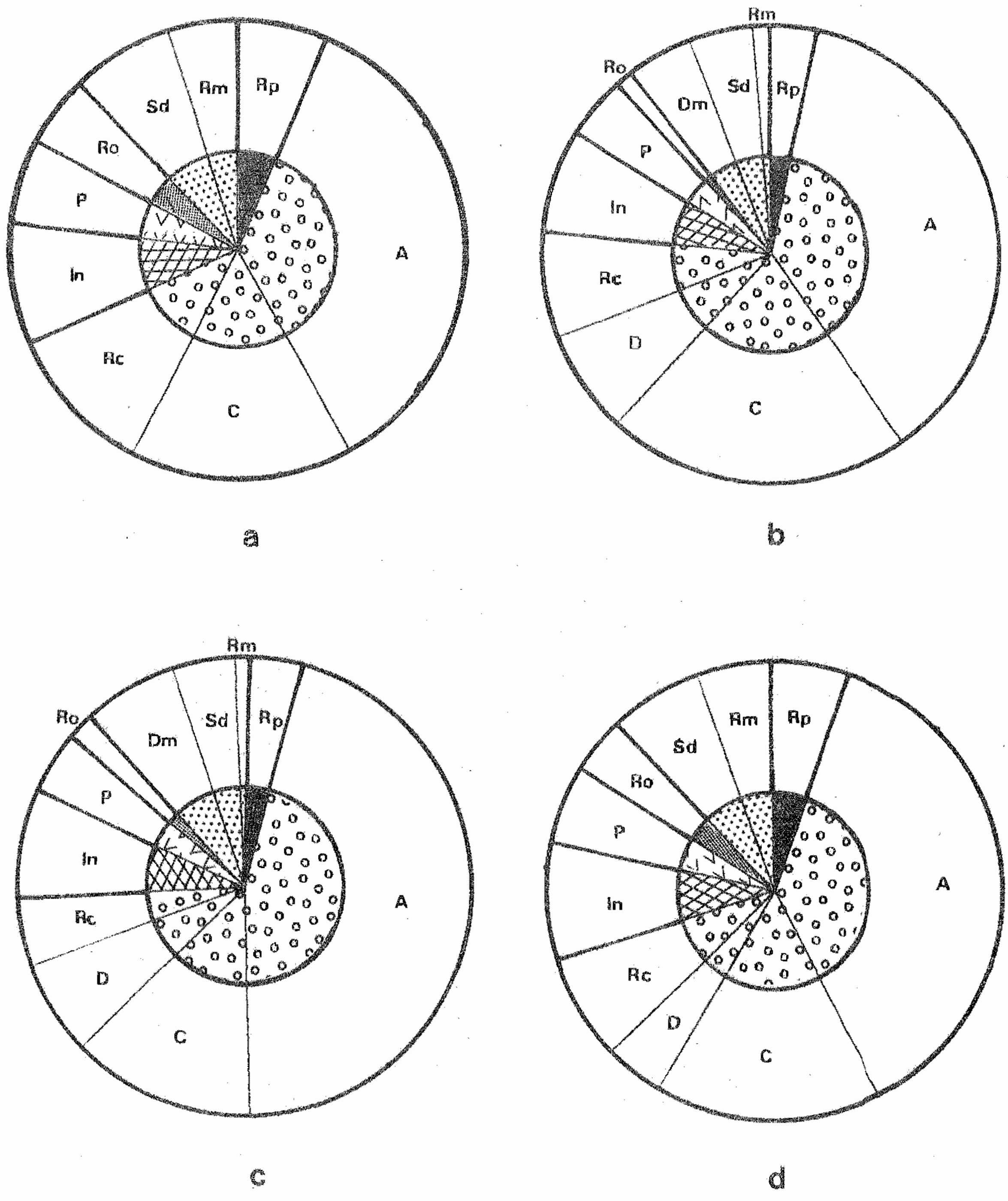


Fig. 6:15 : Proportions of prey groups forming the diets from all sampling sites combined: (a) 1976/77 day samples; (b) 1978 day samples; (c) 1978 night samples and; (d) grand total over all samples.

as mysids and cumaceans were more abundant in diets at beach sites, whereas insects and gastropods were frequently ingested in the estuary. Amphipod species, which formed major dietary items of fish at beach and estuary sites, were less important at the channel entrance. Polychaetes were the major prey component of benthic fish at this site while benthopelagic species preyed mainly on planktonic copepods (see Section 6:6:4).

The total dietary compositions of fishes for day and night samples in 1978 were represented by identical major components and in very similar proportions (Fig. 6:15). Supportive evidence from food charts for the combined 1976/77 data and the grand total over both years indicated that this structure may be a good representation of trends in prey utilization by fishes in this estuarine system.

Amphipods were the major prey group ingested throughout the sampling period and comprised over one-third of the total food habit. The combined average proportion of amphipods and copepods was approximately 58% but the ratio of the former to the latter was higher at night than at day. Robertson and Howard (1978) have shown that facultative zooplankton such as amphipods move into the water column at night where they become available food for planktivores. In addition, some planktivorous fishes that normally preyed on copepods during the day switched to feeding on amphipods at night.

Vegetation was relatively unimportant as food to this fish community and the average proportion of the diet was less than 5%. Nevertheless, the abundance and diversity of prey components at both specific and class levels, were higher at vegetated sites than at adjacent non-vegetated sites. Kikuchi (1974) attributed similar observations to a greater diversity of micro-habitats amongst seagrass beds.

Specific Components

Food habits of marine fishes have been shown to vary, for size of individuals (e.g. Bell, 1980), between localities (e.g. Green, 1968) and temporally (e.g. Robertson, 1980). Data for each species was collected and summarized so this information could be extracted. However, as the overall faunal patterns are most relevant to this study, only the total food charts for the common species are presented (Appendix 6:3). More detailed information is available as ancillary data.

6:6:3 Feeding Habits

The food and feeding habits of fish species are important in characterising their roles within a community. Food habits relate to the diet of a species whereas feeding habits are behavioural traits relating to the search for and ingestion of food (Lagler *et al.*, 1962). Fish are generally diverse feeders with many modes of feeding (Kapoor *et al.*, 1975). They are represented at lowest levels by detritivores and herbivores, by carnivores at the highest trophic levels, and thus play an important trophic role in aquatic environments.

The feeding habits of fishes in this study were characterised by their feeding strategies, food size selection and type of guild (Table 6:10). Fishes were classed as either carnivores, planktivores or omnivores, according to Thomson (1959), based on their feeding strategies. Those species ingesting mainly small food items, compared to the size of the stomach or intestinal bulb, were described as microphagous; those feeding on large items were known as macrophagous. Fish guilds, or groups of species exploiting a common resource in a similar manner (Root, 1967), were categorised as browsers, pickers or grazers. The assessment of

Species	Number individ-uals ex-amined	Number individ-uals with food	Feeding types Major strategy	Guild	Prey size	Food divers-ity	Major prey groups	Fish pred-ation	Append-dix number
Gymnapistes marmoratus	202	121	CI	B	Ma	S	amphiphods, decapods	A	6:3:3
Pseudaphritis urvillii	175	148	CI	B	Ma	S	decapods, amphipods	A	6:3:6
Anguilla australis	21	18	CI	B	Ma	S	amphipods,decapods,isopods	A	6:3:1
Pseudophycis bachus	8	7	CI	B	Ma	S	mysids, decapods	-	6:3:1
Cristiceps australis	35	27	CI	B	Ma	E	amphipods, decapods	A	6:3:6
Scorpaena ergastulorum	12	10	CI	B	Ma	E	amphipods, decapods	-	6:3:3
Favonigobius tamarensis	621	583	CI	B	Mi	S	amphipods	A	6:3:6
Nesogobius sp.2	359	302	CI	B	Mi	S	amphipods, polychaetes	L	6:3:6
Crapatalus arenarius	205	89	CI	B	Mi	S	amphipods	-	6:3:5
Pseudogobius olorum	121	111	CI	B	Mi	S	amphipods	-	6:3:7
Tasmanogobius sp.3	19	19	CI	B	Mi	S	amphipods	-	6:3:7
Urocampus carinirostris	76	48	CI	P	Mi	S	copepods, amphipods	-	6:3:2
Syngnathus tuckeri	18	14	CI	P	Mi	S	amphipods, copepods	-	6:3:3
Stigmatopora nigra	468	371	CI	P	Mi	E	copepods, amphipods	L	6:3:3
Caranx georgianus	25	18	CI	P/G	Mi	S	amphipods, mysids	-	6:3:4
Sillago bassensis	13	8	CI	P/G	Mi	S	amphipods, mysids	-	6:3:4
Acanthopagrus butcheri	37	22	CI	G	Ma/Mi	E	decapods, amphipods	A	6:3:5
Rhombosolea tapirina	473	365	CI	G	Mi	E	amphipods, polychaetes	-	6:3:8
Ammotretis rostratus	367	272	CI	G	Mi	E	amphipods, polychaetes	L	6:3:7
Ammotretis liturata	69	40	CI	G	Mi	E	amphipods, cumaceans	L	6:3:7
Contusus richei	61	58	CI	G	Mi	S	amphipods	-	6:3:9
Brachaluteres jacksonianus	20	13	CI	G	Mi	S	amphipods	-	6:3:8
Platycephalus bassensis	11	10	CI/P	B	Ma	E	decapods, fish	A	6:3:4
Arripis trutta	569	510	PC	P	Ma/Mi	E	amphipods, mysids, copepods	A/L	6:3:4
Engraulis australis	20	15	PC	P	Mi	E	copepods	-	6:3:1
Atherinosoma microstoma	1432	1232	PC	P/G	Mi	E	amphipods, insects	L	6:3:2
Atherinosoma presbyteroides	1301	1169	PC	P/G	Mi	E	copepods, amphipods	L	6:3:2
Galaxias maculatus	103	40	PI	P/G	Mi	E	insects, amphipods	-	6:3:1
Aldrichetta forsteri	1379	1129	PI (0)	P/G	Mi	E	insects,copepods,amphipods	L	6:3:5
Hyporhamphus melanochir	285	258	0	P	Mi	E	seagrass, copepods	L	6:3:2
Neoodax balteatus	32	29	0	G	Mi	E	gastropods,amphipods,decapods	L	6:3:5
Acanthaluteres spilomelanurus	31	22	0	G	Mi	E	amphipods, red algae	-	6:3:8
Penicipelta vittiger	25	9	0	G	Mi	S	bivalves, amphipods	-	6:3:8
Meuschenia freycineti	54	38	0	G	Ma/Mi	E	seagrass, decapods, amphipods	-	6:3:9

Table 6:10. Feeding types and major prey groups of the most abundant fishes caught in this study. Major strategy: CI, carnivorous on invertebrates; P, piscivorous; PC, planktivorous; PI, planktivorous (largely on insects); O, omnivorous; Guild: B, browser; P, picker; G, grazer. Prey size: Ma, macrophagous; Mi, microphagous. Food diversity: S, stenophagous; E, euryphagous. Fish predation: A, on adults; L, on larvae. Food charts of each species are given in Appendix 6:3.

feeding types was based only on the 34 most abundant species for which dietary data were reasonably comprehensive. Of these, 23 were carnivores feeding mainly on invertebrates and only 9 ingested more than 1% plant material.

Seventeen species consumed fish but only *Platycephalus bassensis* was predominantly piscivorous. Other Australian platycephalids are also piscivores (Lewis, 1971; Bell, 1980). The larger macrophagous species, *Anguilla australis, Gymnapistes marmoratus, Acanthopagrus butcheri, Pseudaphritis urvillii* and *Cristiceps australis,* and one microphag , *Favonigobius tamarensis,* dieted on adults of smaller atherinids, gobiids and syngnathids. The remaining species were predominantly microphagous but preyed seasonally on juveniles and larval fishes. Major prey items included post-larval atherinids and pleuronectids but in all cases they comprised only a small proportion of the prey component.

All macrophagous carnivores were browsers while most microphagous carnivores were pickers or grazers; carnivorous species were mostly stenophagous.

Six species were identified as planktivores: *Engraulis australis, Atherinosoma microstoma, A. presbyteroides, Arripis trutta, Galaxias maculatus* and *Aldrichetta forsteri.* Of these, *Galaxias maculatus* and *Aldrichetta forsteri* ingested larger total proportions of insects than crustaceans while the reverse was true for the remaining species. The proportion of insects, in the diets of fishes, appeared to be closely correlated with their availability. They were most important as food in brackish upper areas of the estuary where they were most abundant.

The planktivores were euryphagous pickers and, although all fed mainly on plankton, *Galaxias maculatus, Atherinosoma microstoma, A. presbyteroides* and *Aldrichetta forsteri* sometimes grazed on benthic invertebrates. Some species of mullet are partly detritivorous (Thomson, 1974; Rigby, 1979) and several adults of *Aldrichetta forsteri* sampled from the estuary had been actively feeding on detritus.

No species were totally herbivorous, although 5 species were characteristically omnivorous: *Hyporhamphus melanochir, Neoodax balteatus, Penicipelta vittiger, Acanthaluteres spilomelanurus* and *Meuschenia freycineti*. The seagrass, *Zostera muelleri*, dominated the gut contents of *Hyporhamphus melanochir* and *Meuschenia freycineti* specimens examined. Collette (1972) observed that garfishes were largely herbivorous and studies of the food habits of *Hyporhamphus melanochir* from Western Australia (Thomson, 1957b) supported this argument. Bell *et al*. (1978b) also found that the diets of juvenile *Meuschenia freycineti* in Port Hacking consisted primarily of another seagrass, *Posidonia australis*. Nevertheless, crustaceans still comprised a significant proportion of the diets of both species.

The remaining omnivores consumed smaller proportions (less than 30%) of plant material. Although this vegetative proportion was dominated by seagrasses in the case of *Neoodax balteatus*, red algae was a more important component for the other leatherjacket species. Apart from a picker, *Hyporhamphus melanochir*, the omnivorous species were grazers and all were euryphagous.

The temporal feeding pattern of many species was difficult to assess because of a lack of continuous and replicate samples throughout the 24 hour period. Some species such as *Arripis trutta* were clearly more active during the day whereas *Gymnapistes marmoratus* and *Anguilla australis* were predominantly nocturnal feeders. *Favonigobius tamarensis* exhibited no diurnal, nocturnal or crepuscular peaks and appeared to feed continuously. Available information suggested that most species fed in this manner.

6:6:4 Trophic Interactions

Relationships Within Sites

The availability of prey species is important in determining trophic structure in fish communities (Kikuchi, 1974; Robertson and Howard, 1978). Specialised feeders may be excluded from an area by the absence of a particular prey item while facultative feeders may have to switch diets. Trophic structure of fish assemblages at each site are examined below.

Food relationships based on major prey groups and prey species data from the most abundant species at each site was analysed using clustering techniques (see Section 6:3:3).

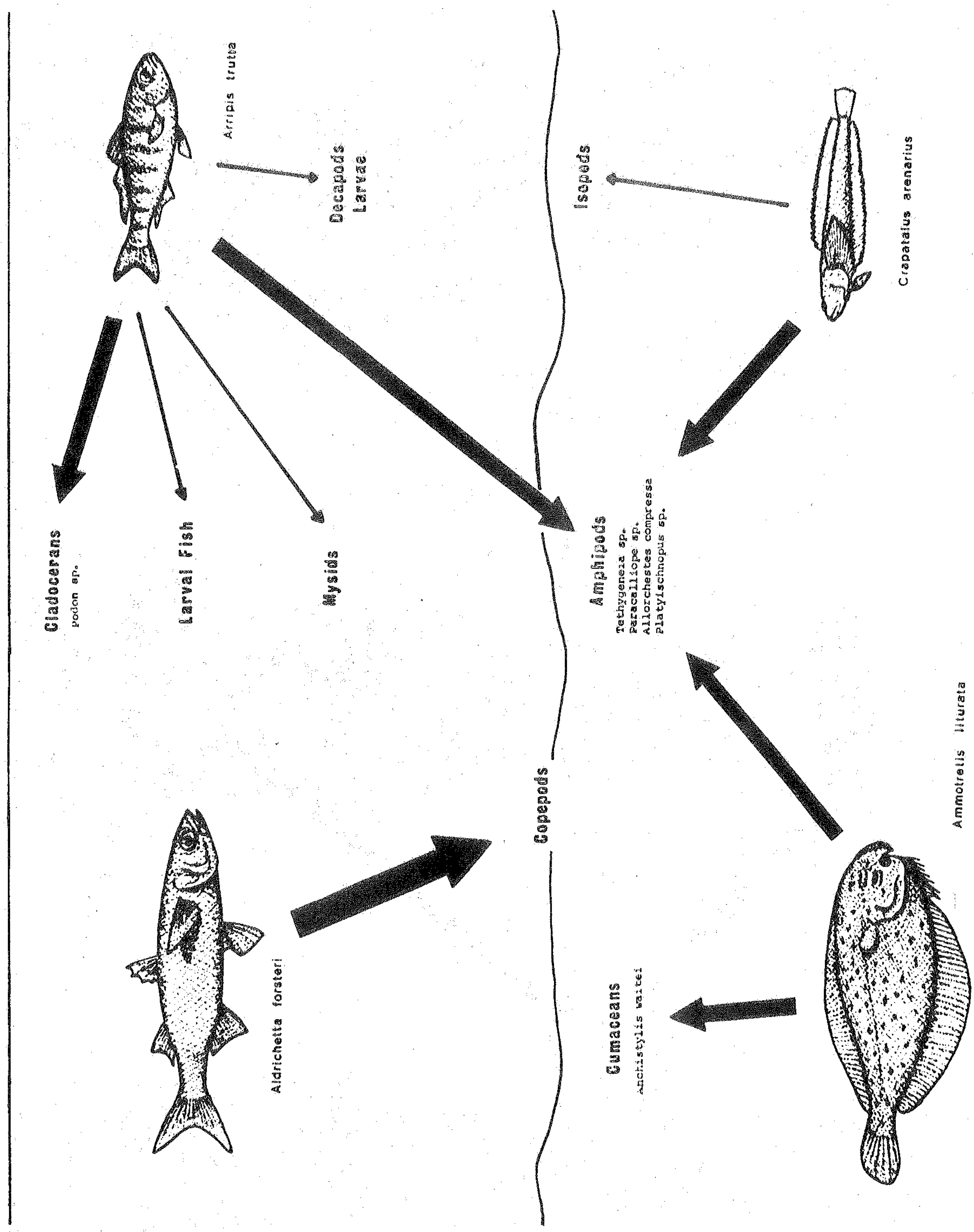
Site 1

The 4 most abundant species at this site had noticeably different food habits (Fig. 6:19, 20). Amphipods were the major prey item exploited by fish at this site (see Fig. 6:13a) and, although these were primary components for *Ammotretis liturata, Crapatalus arenarius* and *Arripis trutta,* the secondary components were different for each species.

The benthopelagic species, *Aldrichetta forsteri,* fed mainly on copepods. A high similarity between *Aldrichetta forsteri* and *Crapatalus arenarius* was possibly attributed to mutually large proportions of organic detritus. *Aldrichetta forsteri* has been regarded as planktivorous (Robertson and Howard, 1978), omnivorous (Thomson, 1957b; 74) and detritivorous (Rigby, 1979). *Crapatalus arenarius* probably ingested sediment and organic detritus incidentally in the process of swallowing prey.

The benthic carnivores, *Ammotretis liturata* and *Crapatalus arenarius,* preyed on a different complement of species from the two benthopelagic species, *Arripis trutta* and *Aldrichetta forsteri* (Fig. 6:27). Low similarities between species based on prey groups and prey species (Appendix 6:4) suggested that the amount of food overlap between the

Fig. 6:16. Food relationships of fishes on Nine Mile Beach (site 1). Arrow widths indicate the importance of prey groups.



abundant species was small.

The food relationships of fishes at this site are summarised in Figure 6:16 .

Site 2

The most abundant species at site 2, exhibiting more variable diets than those at site 1 (Fig. 6:19, 21), was highlighted by the supplementation of estuary derived prey components. Groups such as insects and polychaetes, which were relatively unimportant at the other beach site, were among the major items at this site.

Drifting macrophytic plants, which do not form stands at this location, were represented in the total food habit for the site (see Fig. 6:13a). These components, mainly seagrasses, were washed from the estuary and dominated the diet of the pelagic omnivore *Hyporhamphus melanochir*. Two benthopelagic planktivores, *Aldrichetta forsteri* and *Atherinosoma presbyteroides*, and a benthic planktivore, *Stigmatopora nigra*, preyed mainly on copepods. Amphipods were important components of the food habits of the remaining species, however, the other major prey group differed in each case.

Apart from the presence of a small amount of plant material in the food of fishes collected at this site, the relative compositions of prey groups at beach sites were similar.

Cluster analysis based on prey species indicated the presence of a moderate overlap between *Aldrichetta forsteri*, *Arripis trutta* and *Contusus richei* (Fig. 6:27). These species were predators of a large array of planktonic and benthic invertebrates. Two other correlated species, *Hyporhamphus melanochir* and *Atherinosoma presbyteroides*, fed solely on plankton or detached seagrass and, hence, species that were commonly ingested during the day by benthic fishes were absent from their diets.

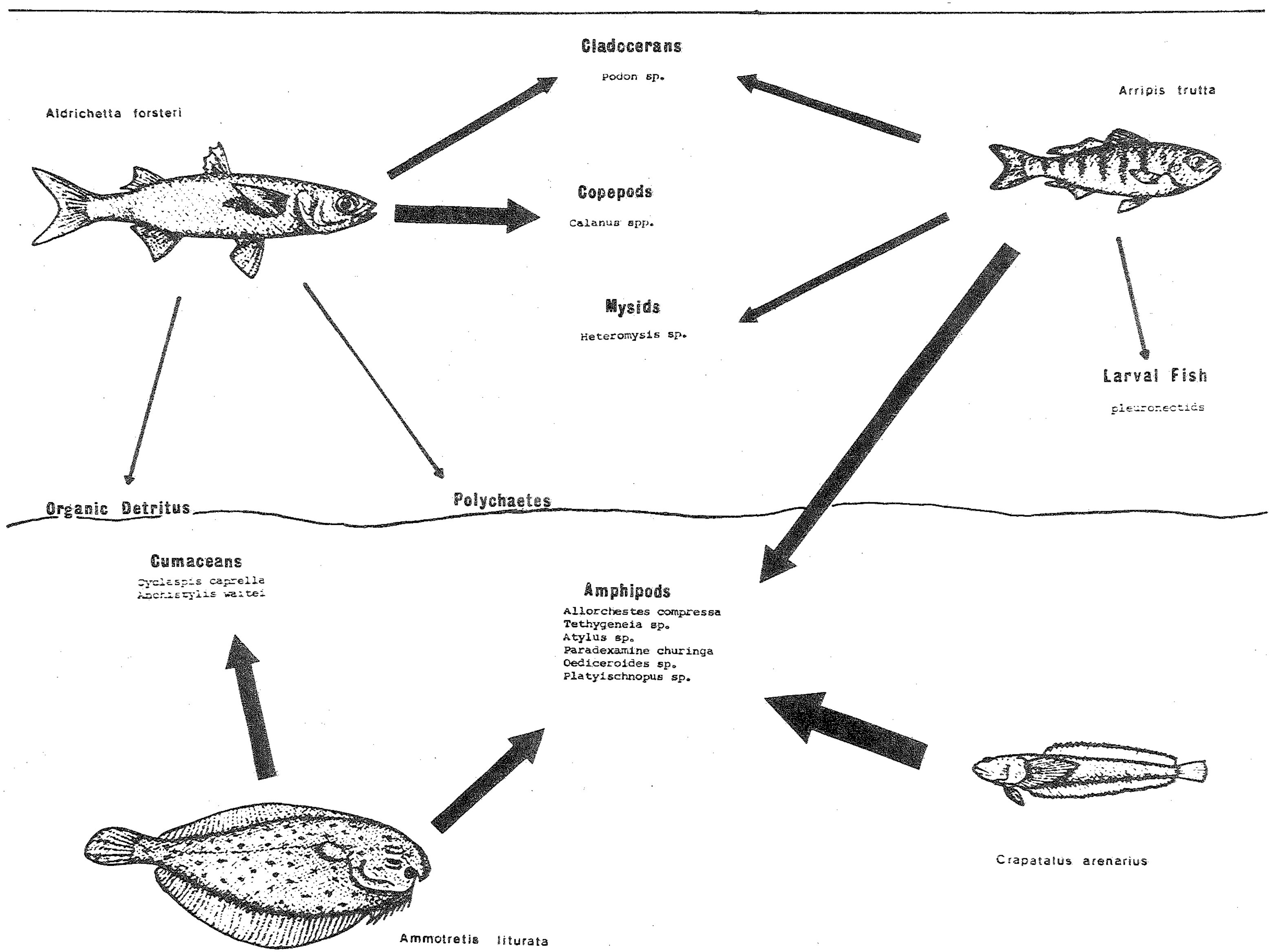


Fig. 6:17. Food relationships of fishes near the barway of the estuary (site 2). Arrow widths indicate the importance of prey groups.

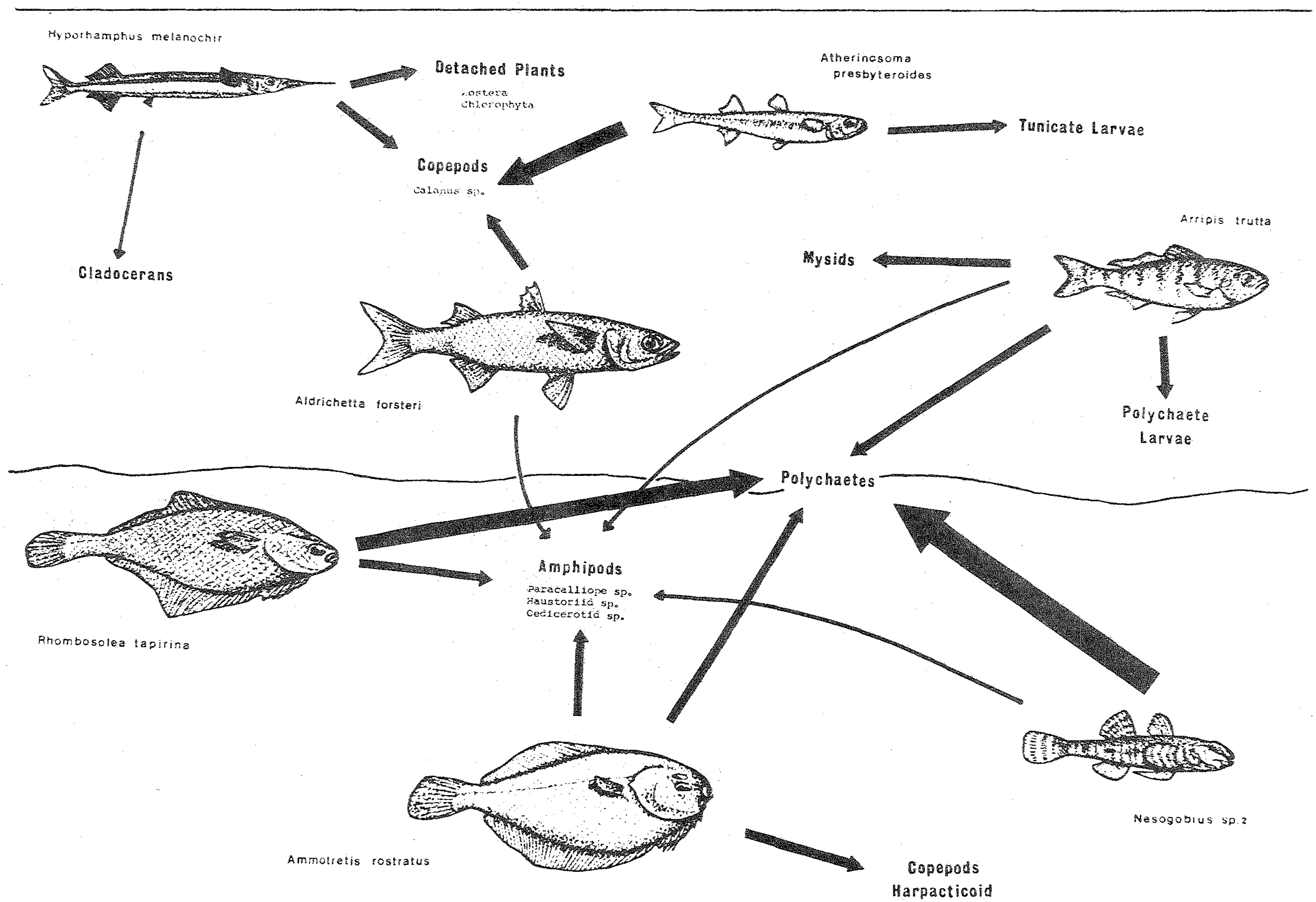


Fig. 6:18. Food relationships of fishes in the entrance channel of the estuary. Arrow widths indicate the importance of prey groups.

The food relationships of fishes at this site are summarised in Figure 6:17.

Site 3

Cluster analysis of food habits of species from this site, based on prey groups, demonstrated the existence of dietary relationships between ecologically similar species (Fig. 6:19, 22).

Hyporhamphus melanochir and *Atherinosoma presbyteroides* were again clustered together but, although *Hyporhamphus melanochir* remained omnivorous, the proportional amount of copepods and miscellaneous material ingested was higher than at site 2.

The benthic grazing flounders, *Ammotretis rostratus* and *Rhombosolea tapirina,* had the highest similarities. Polychaetes and amphipods were important food components of these species. The large copepod element in *Ammotretis rostratus* was due to the presence of benthic harpacticoids rather than planktonic calanoids which are normally consumed by the planktivorous feeders.

Rhombosolea tapirina exhibited comparatively high similarities to each of the 4 remaining species (Appendix 6:4) of which *Nesogobius* sp. 2 had the most similar diet; in each case polychaetes and amphipods were among the major components. Mysids, amphipods and copepods were more important to *Arripis trutta, Atherinosoma microstoma* and *Aldrichetta forsteri* respectively; the last 2 species also consumed moderate amounts of insects. The total food habit (see Fig. 6:13a) stressed the importance of copepods, amphipods and polychaetes as food items for fish at this site.

Clustering, based on prey species, provided clear aggregations of species on their feeding strategies (Fig. 6:27).

The food relationships of fishes at this site are summarised in Figure 6:18.

Fig. 6·19 : Key to prey groups from food charts in Figs. 6:20 - 26.

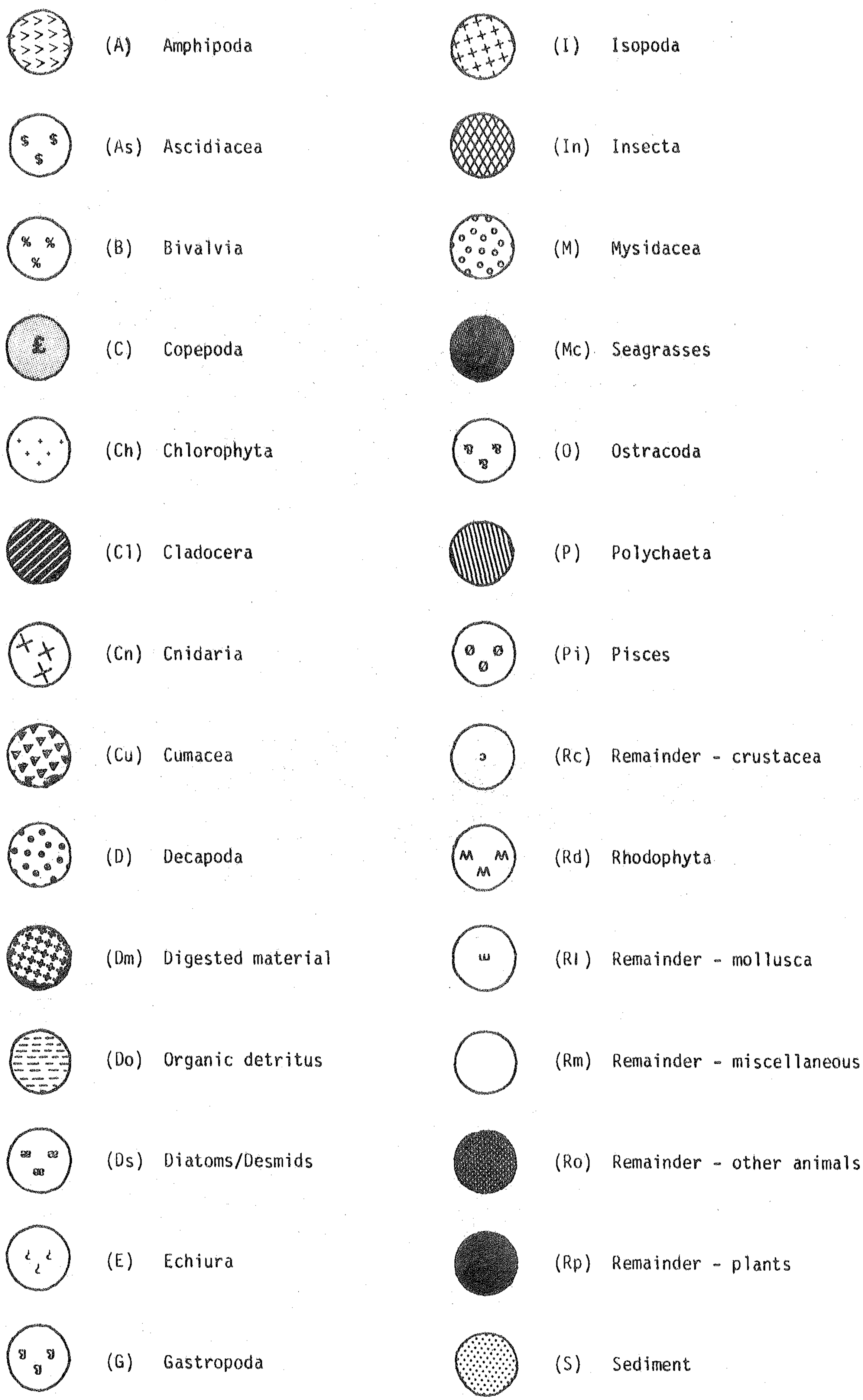
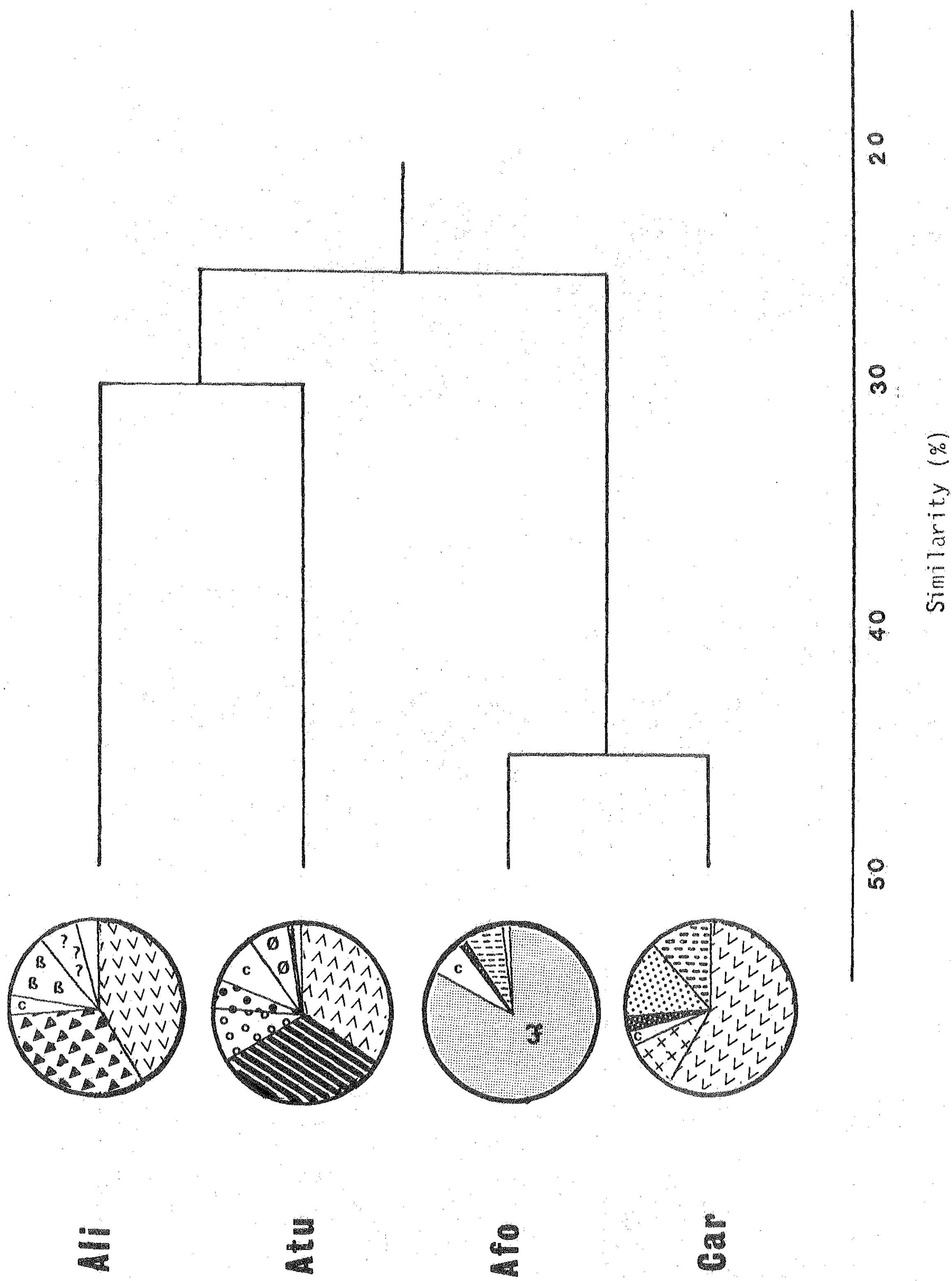


Fig. 6:20. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 1 based on prey groups. Ali, *Ammotretis liturata*. Atu, *Arripis trutta*. Afo, *Aldrichetta forsteri*. Car, *Crapatalus arenarius*.



Ali
Atu
Afo
Gar
50
40
30
20
Similarity (%)

Fig. 6:21. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 2 based on prey groups. Hme, *Hyporhamphus melanochir*. Aps, *Atherinosoma presbyteroides*. Afo, *Aldrichetta forsteri*. Ali, *Ammotretis liturata*. Atu, *Arripis trutta*. Sni, *Stigmatopora nigra*. Car, *Crapatalus arenarius*.

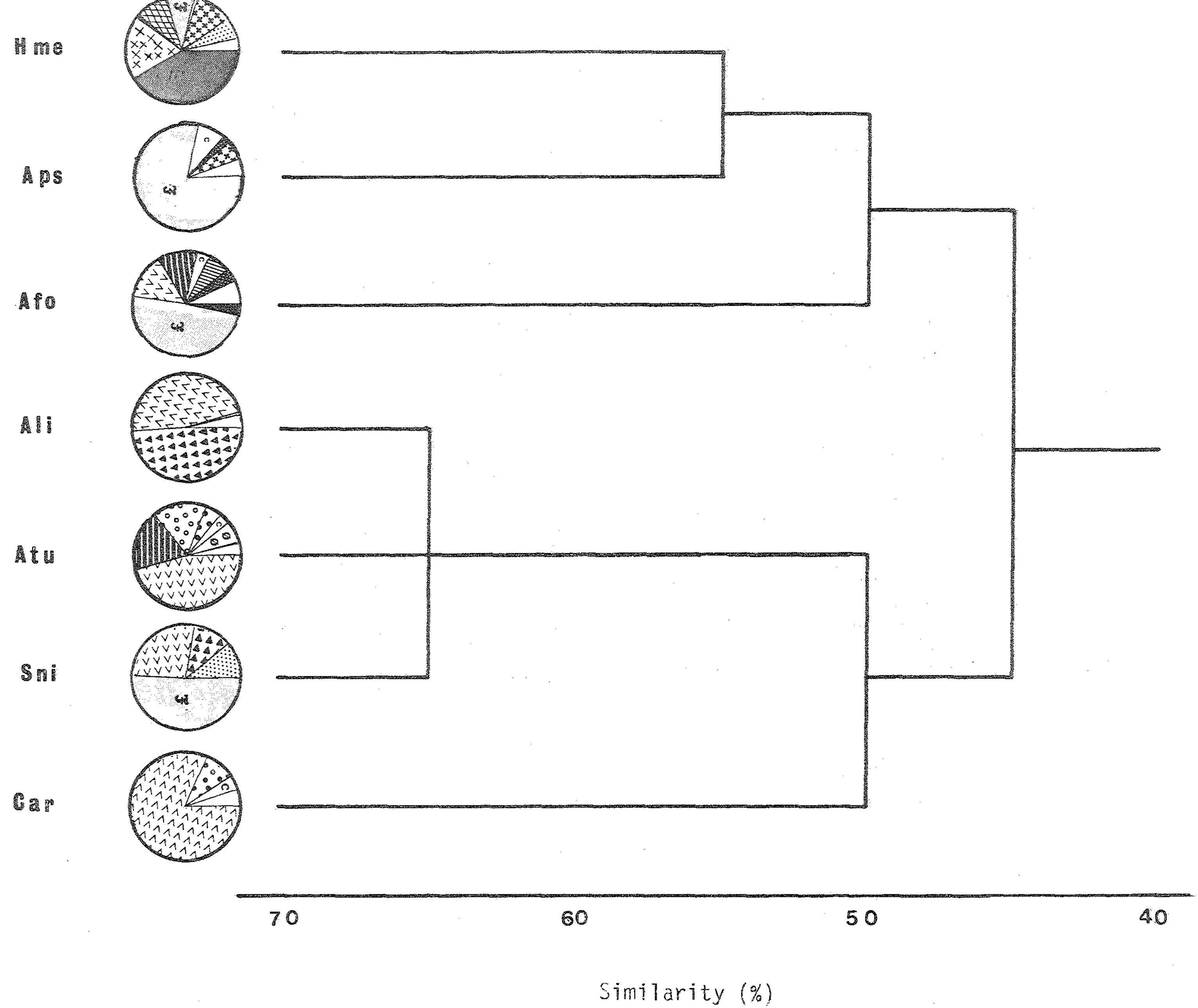
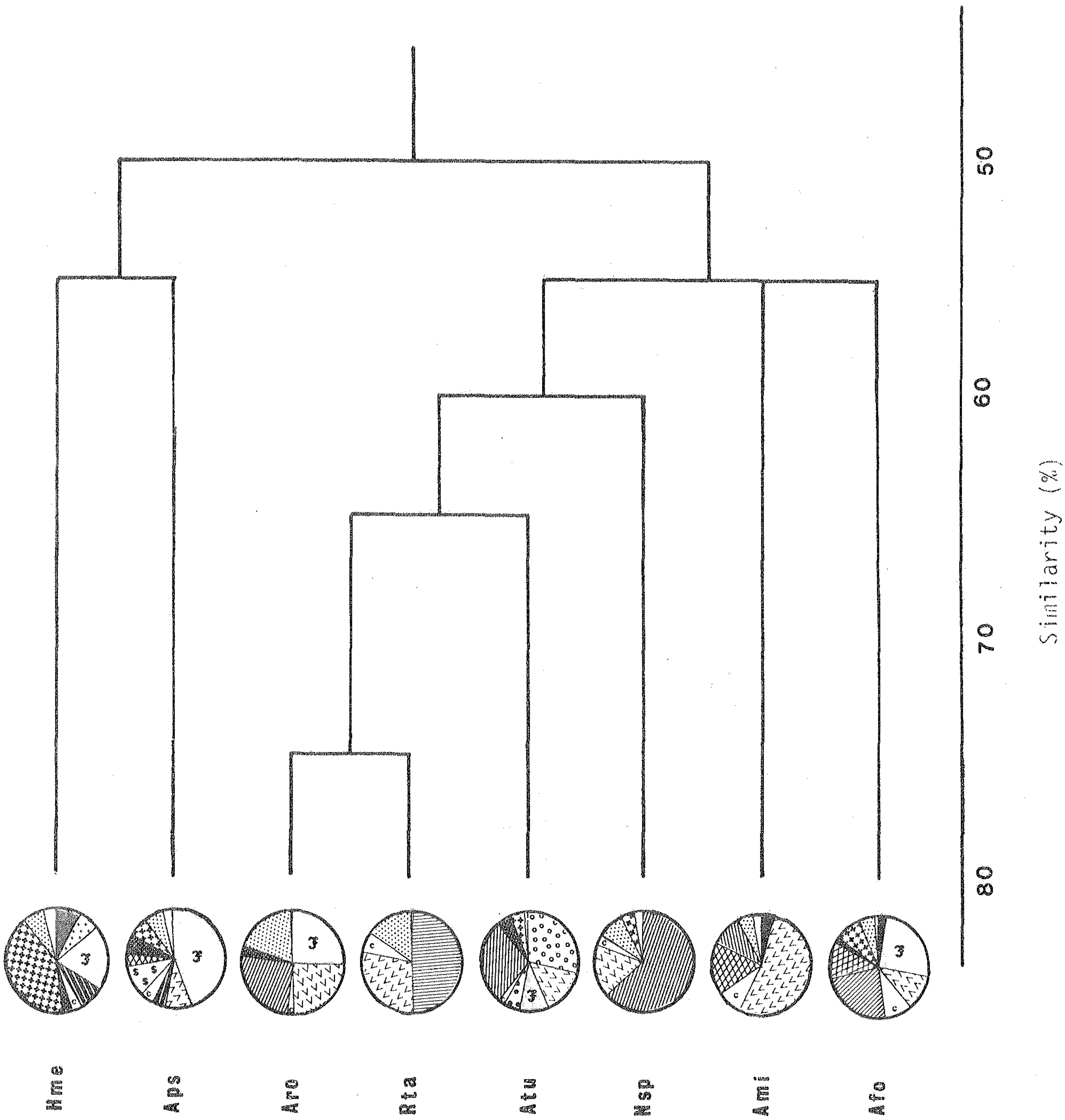
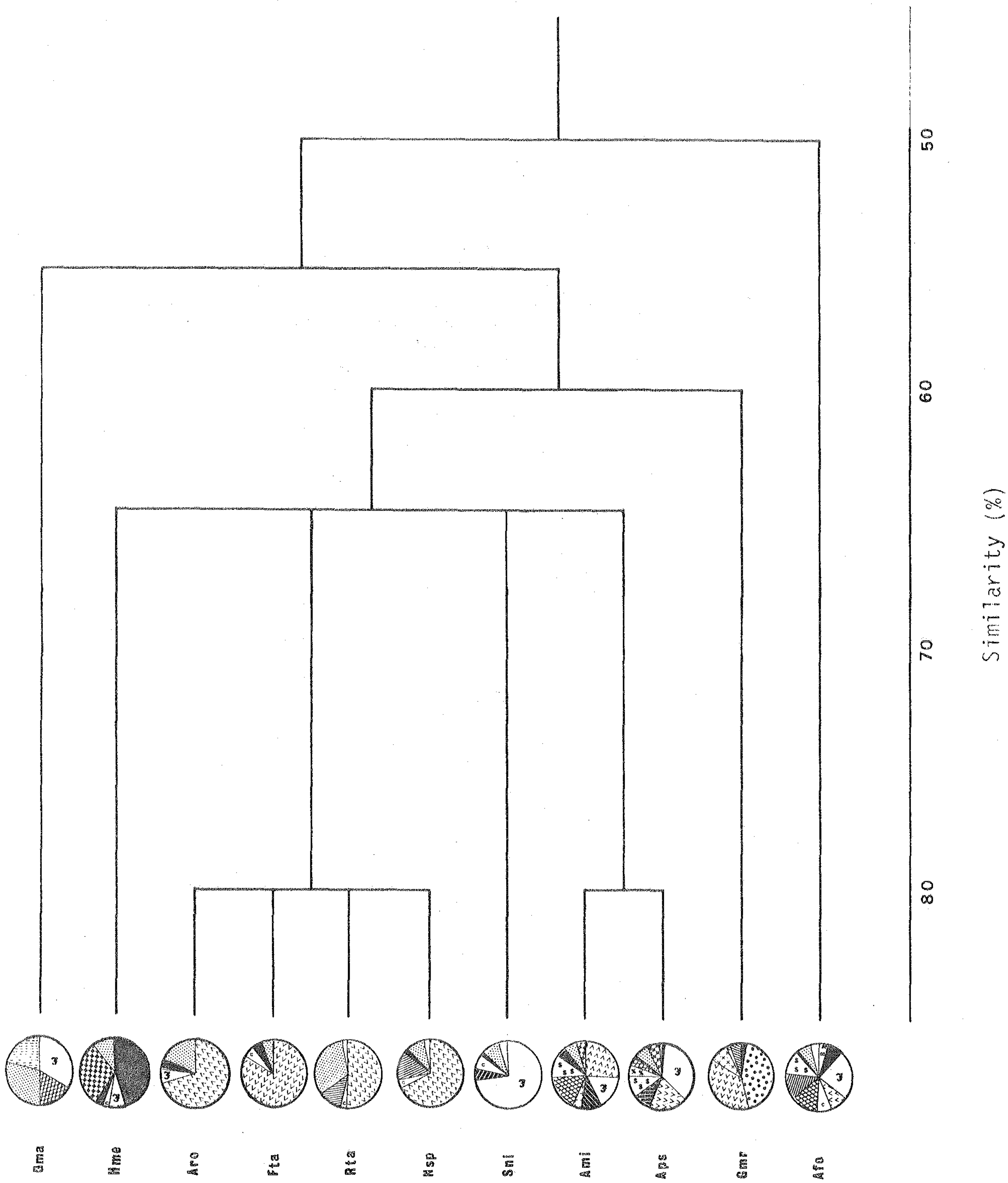

Hme
Aps
Afo
Ali
Atu
Sni
Car
70
60
50
40
Similarity (%)

Fig. 6:22. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 3 based on prey groups. Hme, *Hyporhamphus melanochir*. Aps, *Atherinosoma presbyteroides*. Atu, *Arripis trutta*. Rta, *Rhombosolea tapirina*. Aro, *Ammotretis rostratus*. Nsp, *Nesogobius* sp. 2. Ami, *Atherinosoma microstoma*. Afo, *Aldrichetta forsteri*.



Hme
Aps
Aro
Rta
Atu
Nsp
Ami
Afo
50
60
70
80
Similarity (%)

Fig. 6:23. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 4 based on prey groups.. Gma, *Galaxias maculatus*. Hme, *Hyporhamphus melanochir*. Aro, *Ammotretis rostratus*. Fta, *Favonigobius tamarensis*. Rta, *Rhombosolea tapirina*. Nsp, *Nesogobius* sp. 2. Sni, *Stigmatopora nigra*. Ami, *Atherinosoma microstoma*. Aps, *Atherinosoma presbyteroides*. Gmr, *Gymnapistes marmoratus*. Afo, *Aldrichetta forsteri*.



50
60
70
80
Similarity (%)
Ema
Hme
Aro
Fta
Rta
Hsp
Sni
Ami
Aps
Gmr
Afo

Fig. 6:24. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 5 based on prey groups. Rta, *Rhombosolea tapirina*. Fta, *Favonigobius tamarensis*. Ami, *Atherinosoma microstoma*. Hme, *Hyporhamphus melanochir*. Aps, *Atherinosoma presbyteroides*. Afo, *Aldrichetta forsteri*.

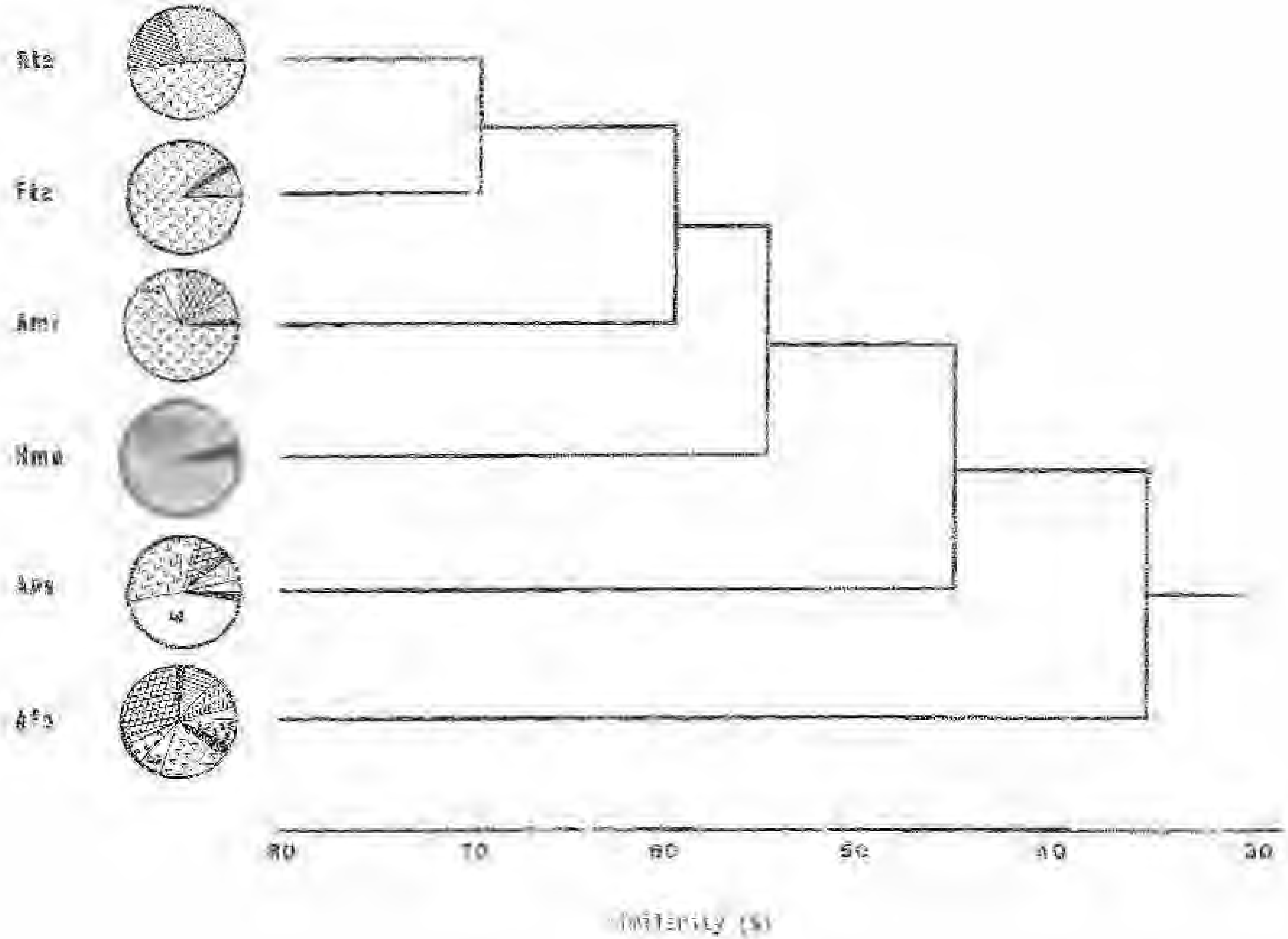
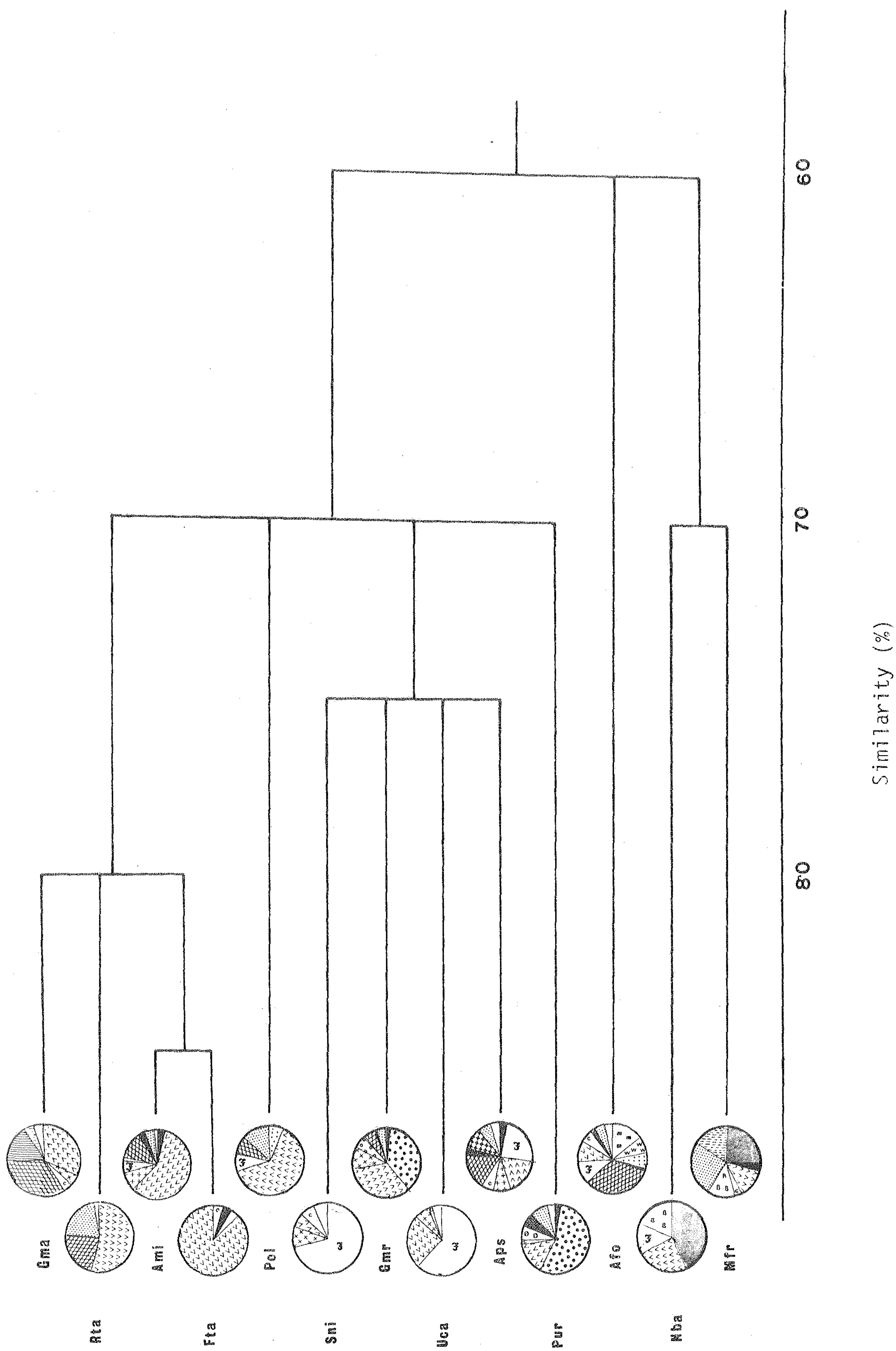

80
70
60
50
40
30
Similarity (%)

Fig. 6:25. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 6 based on prey groups. Gma, *Galaxias maculatus*. Rta, *Rhombosolea tapirina*. Ami, *Atherinosoma microstoma*. Fta, *Favonigobius tamarensis*. Pol, *Pseudogobius olorum*. Sni, *Stigmatopora nigra*. Gmr, *Gymnapistes marmoratus*. Uca, *Urocampus carinirostris*. Aps, *Atherinsoma presbyteroides*. Pur, *Pseudaphritis urvillii*. Afo, *Aldrichetta forsteri*. Nba, *Neoodax balteatus*.. Mfr, *Meuschenia freycineti*.



Gma
Rta
Ami
Fta
Pol
Sni
Gmr
Uca
Aps
Pur
Afo
Nba
Mfr
60
70
80
Similarity (%)

Fig. 6:26. Food charts and a dendrogram of similarity for centroid cluster analysis of the diets of major species at sample site 7 based on prey groups. Afo, *Aldrichetta forsteri*. Ami, *Atherinosoma microstoma*. Fta, *Favonigobius tamarensis*. Pol, *Pseudogobius olorum*. Gmr, *Gymnapistes marmoratus*. Pur, *Pseudaphritis urvillii*. Aps, *Atherinosoma presbyteroides*.

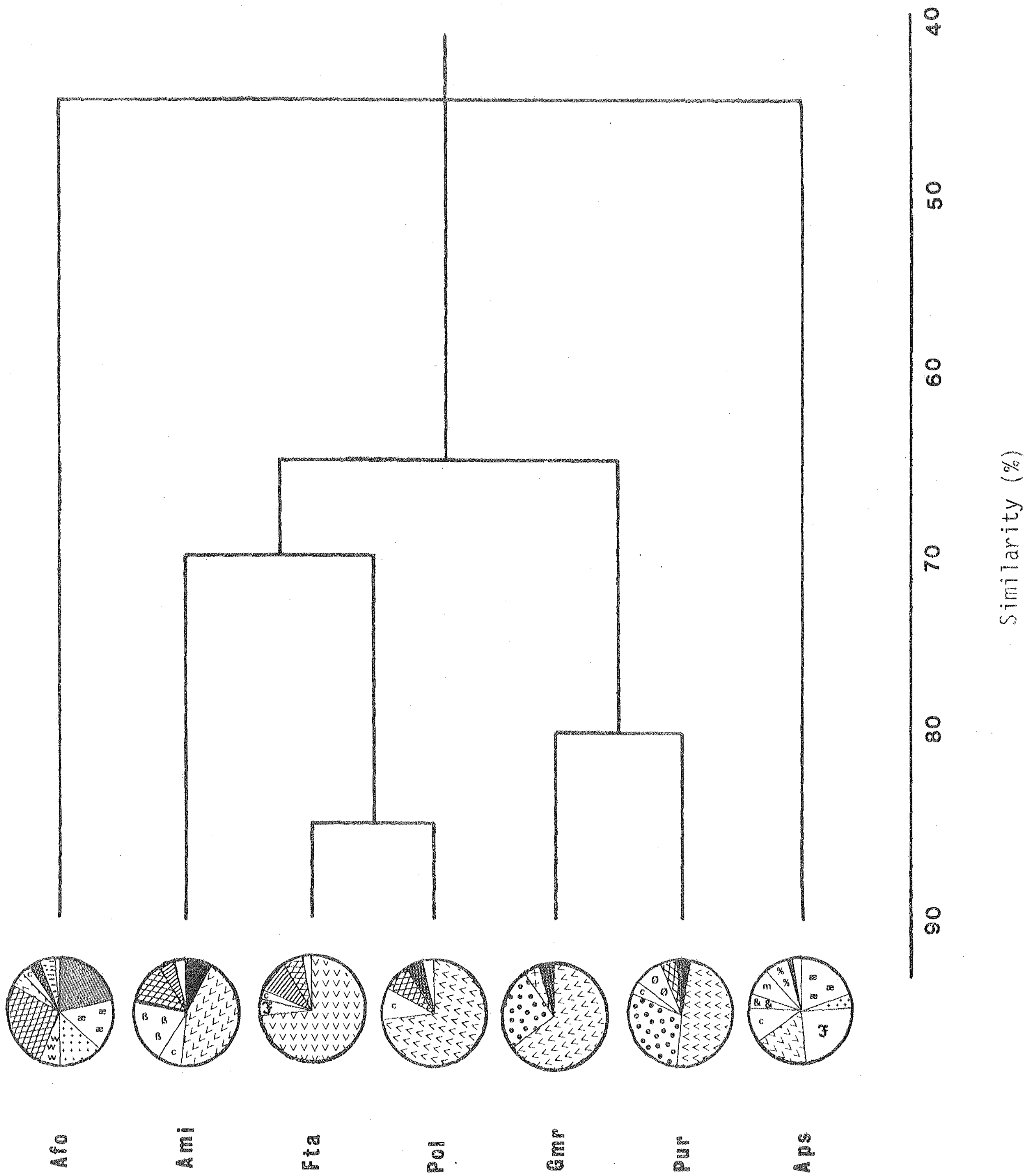

Afo
Ami
Fta
Pol
Gmr
Pur
Aps
40
50
60
70
80
90
Similarity (%)

Fig. 6:27. Dendrogram of similarity for centroid cluster analysis of the diets of major species at sampling sites (a) 1, (b) 2, (c) 3 and (d) 4 based on prey species. Afo, *Aldrichetta forsteri*. Ali, *Ammotretis liturata*. Ami, *Atherinosoma microstoma*. Aps, *Atherinosoma presbyteroides*. Aro, *Ammotretis rostratus*. Atu, *Arripis trutta*. Car, *Crapatalus arenarius*. Fta, *Favonigobius tamarensis*. Gma, *Galaxias maculatus*. Gmr, *Gymnapistes marmoratus*. Hme, *Hyporhamphus melanochir*. Nsp, *Nesogobius* sp. 2. Rta, *Rhombosolea tapirina*. Sni, *Stigmatopora nigra*.

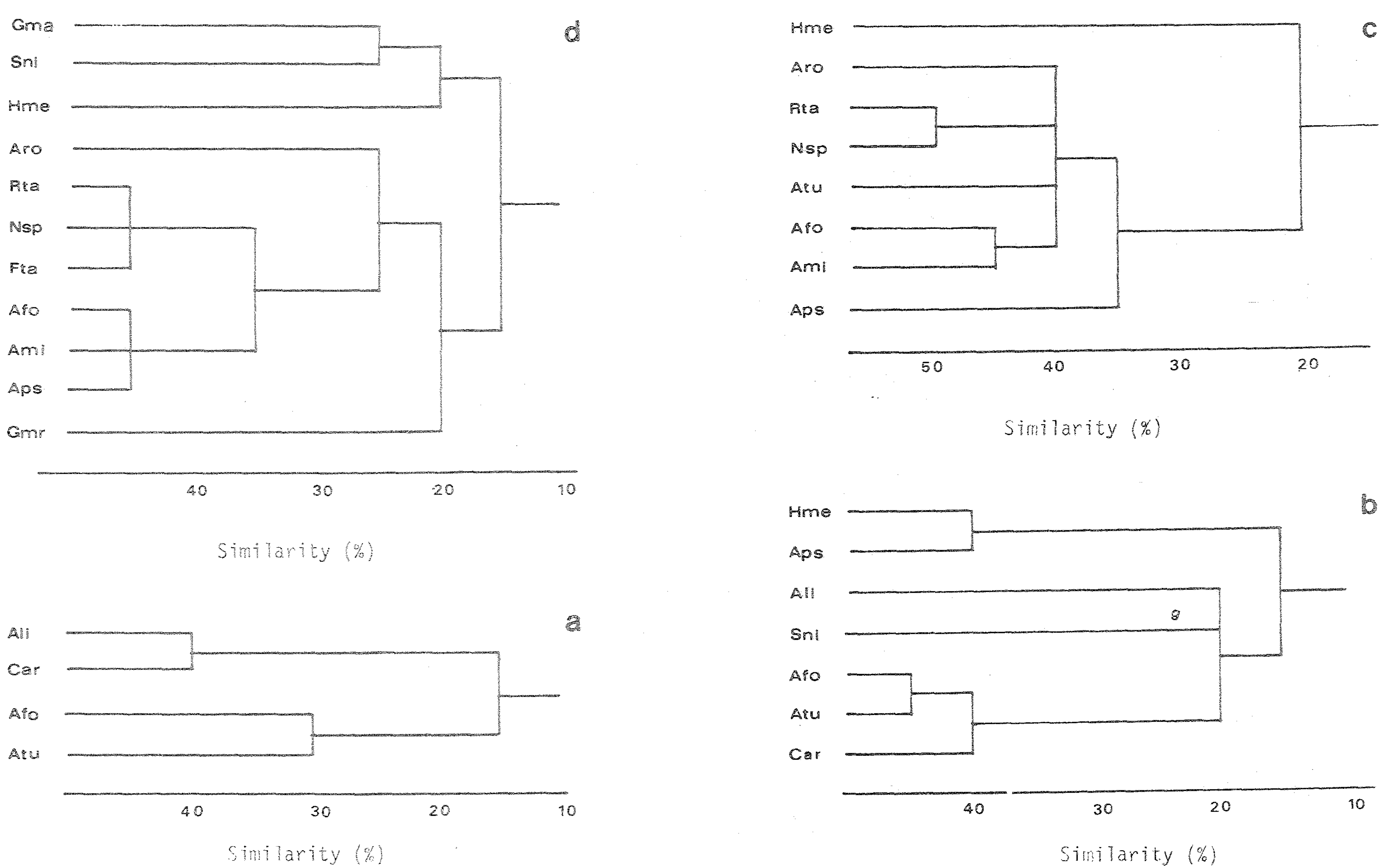
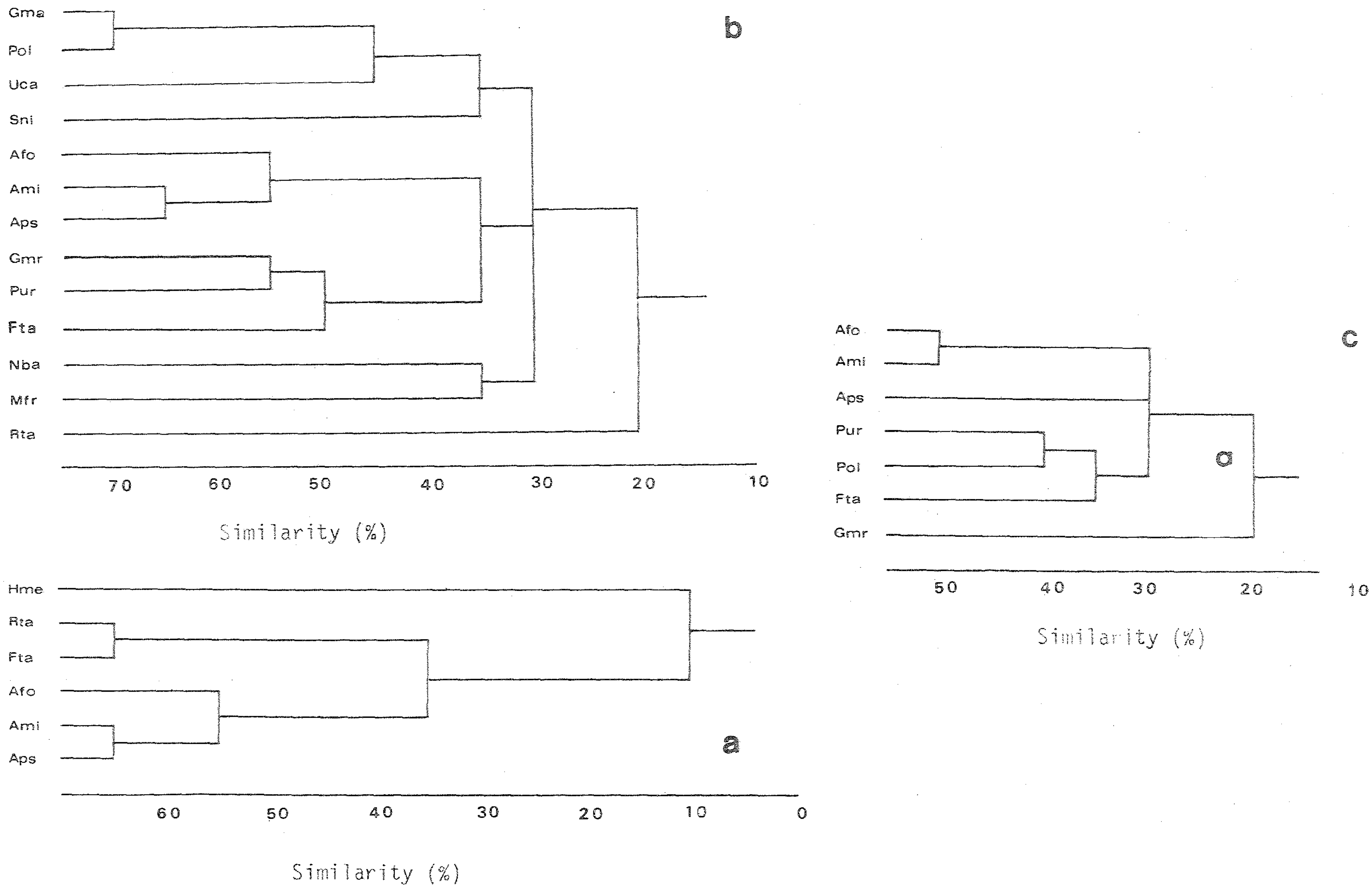

d
Gma
Sni
Hme
Aro
Rta
Nsp
Fta
Afo
Ami
Aps
Gmr
40
30
20
10
Similarity (%)
c
Hme
Aro
Rta
Nsp
Atu
Afo
Ami
Aps
50
40
30
20
Similarity (%)
a
All
Car
Afo
Atu
40
30
20
10
Similarity (%)
b
Hme
Aps
All
Sni
Afo
Atu
Car
40
30
20
10
Similarity (%)

Fig. 6:28. Dendrogram of similarity for centroid cluster analysis of the diets of major species at sampling sites (a) 5, (b) 6 and (c) 7 based on prey species. Afo, *Aldrichetta forsteri*. Ami, *Atherinosoma microstoma*. Aps, *Atherinosoma presbyteroides*. Fta, *Favonigobius tamarensis*. Gma, *Galaxias maculatus*. Gmr, *Gymnapistes marmoratus*. Hme, *Hyporhamphus melanochir*. Mfr, *Meuschenia freycineti*. Nba, *Neoodax balteatus*. Pol, *Pseudogobius olorum*. Pur, *Pseudaphritis urvillii*. Rta, *Rhombosolea tapirina*. Sni, *Stigmatopora nigra*. Uca, *Urocampus carinirostris*.


b
Gma
Pol
Uca
Sni
Afo
Ami
Aps
Gmr
Pur
Fta
Nba
Mfr
Rta
70 60 50 40 30 20 10
Similarity (%)
Hme
Rta
Fta
Afo
Ami
Aps
a
60 50 40 30 20 10 0
Similarity (%)
c
Afo
Ami
Aps
Pur
Pol
Fta
Gmr
a
50 40 30 20 10
Similarity (%)

Site 4

Species at this site exhibited the greatest diversity of food habits of the sites sampled. The high similarity shared between some species amid a wide range of similarities partly reflects this trend (Fig. 6:19, 23).

Flounder (*Rhombosolea tapirina* and *Ammotretis rostratus*) and goby species (*Nesogobius* sp. 2 and *Favonigobius tamarensis*) were shown to consume similar prey groups. In each case, amphipods were the dominant prey item. Polychaetes, in accordance with the situation at site 3, were important to *Rhombosolea tapirina* and *Nesogobius* sp. 2. Such differences may help to minimize competition between confamilials in situations when they have sympatric distributions.

The species of *Atherinosoma* also had similar food habits; planktonic amphipods, copepods, cladocerans and ascidians were ingested by both species. *Aldrichetta forsteri* was also extremely euryphagous but was more omnivorous than the hardyheads at this site.

The remaining species, a microphagous planktivore (*Galaxias maculatus*), a weed-dwelling microphagous carnivore (*Stigmatopora nigra*), a pelagic omnivore (*Hyporhamphus melanochir*) and a macrophagous carnivore (*Gymnapistes marmoratus*), were not closely associated in food habits.

The diets of fishes from this site were dominated by amphipods (see Fig. 6:13a) although copepods were also important. Planktonic ascidian larvae were consumed as an opportunistic seasonal component and were only present in the diet in spring.

Clustering based on the ingestion of prey species (Fig. 6:27) supported the results from the prey group analysis. Similar feeding types, with the exception of *Galaxias maculatus* and *Ammotretis rostratus*, were aggregated. The sampling size of the former was low which could account for its stenophagous food habit and subsequent low similarity to other euryphagous

Fig. 6:29. Food relationships of fishes in the lower estuary (site 4). Arrow widths indicate the importance of prey groups.

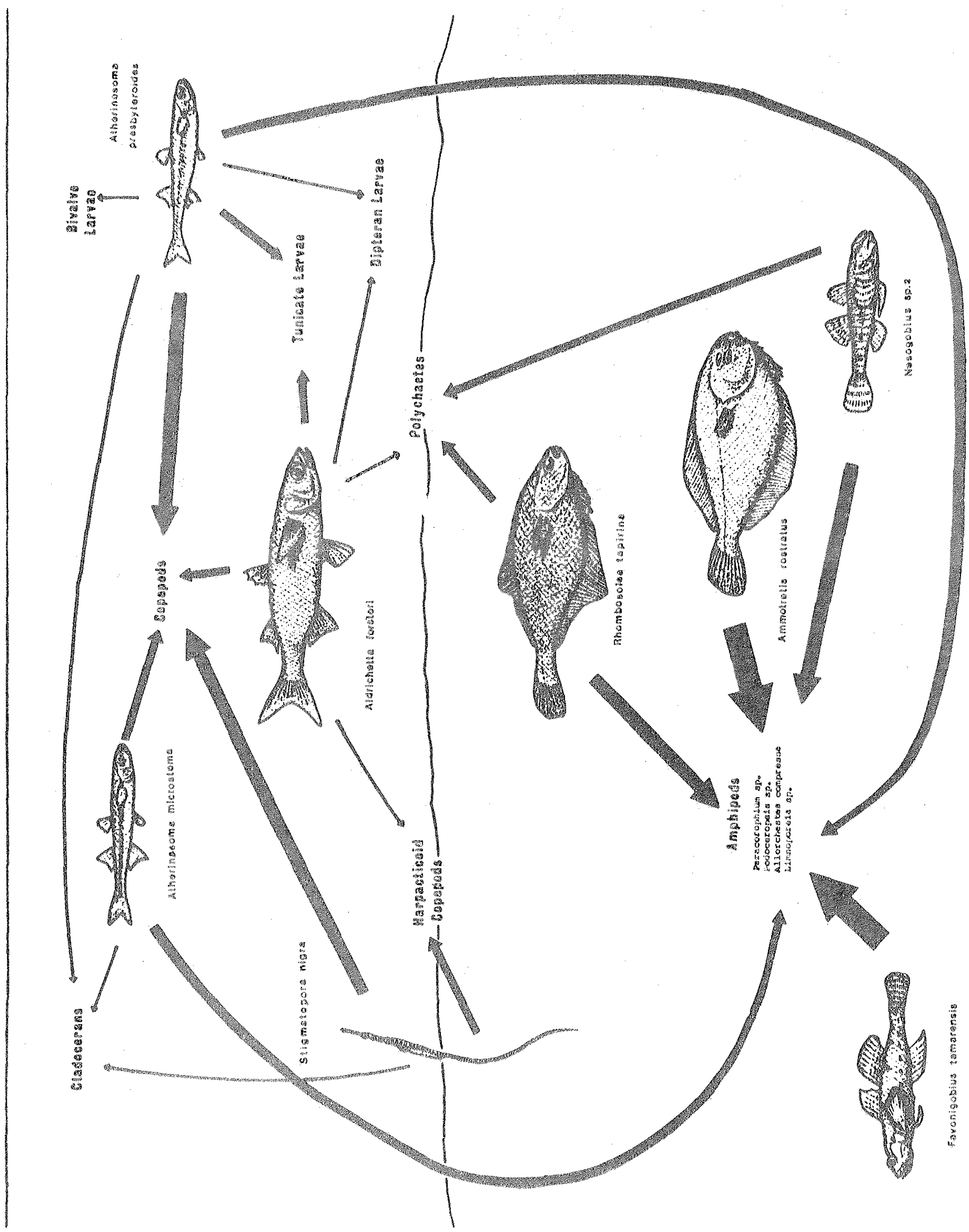
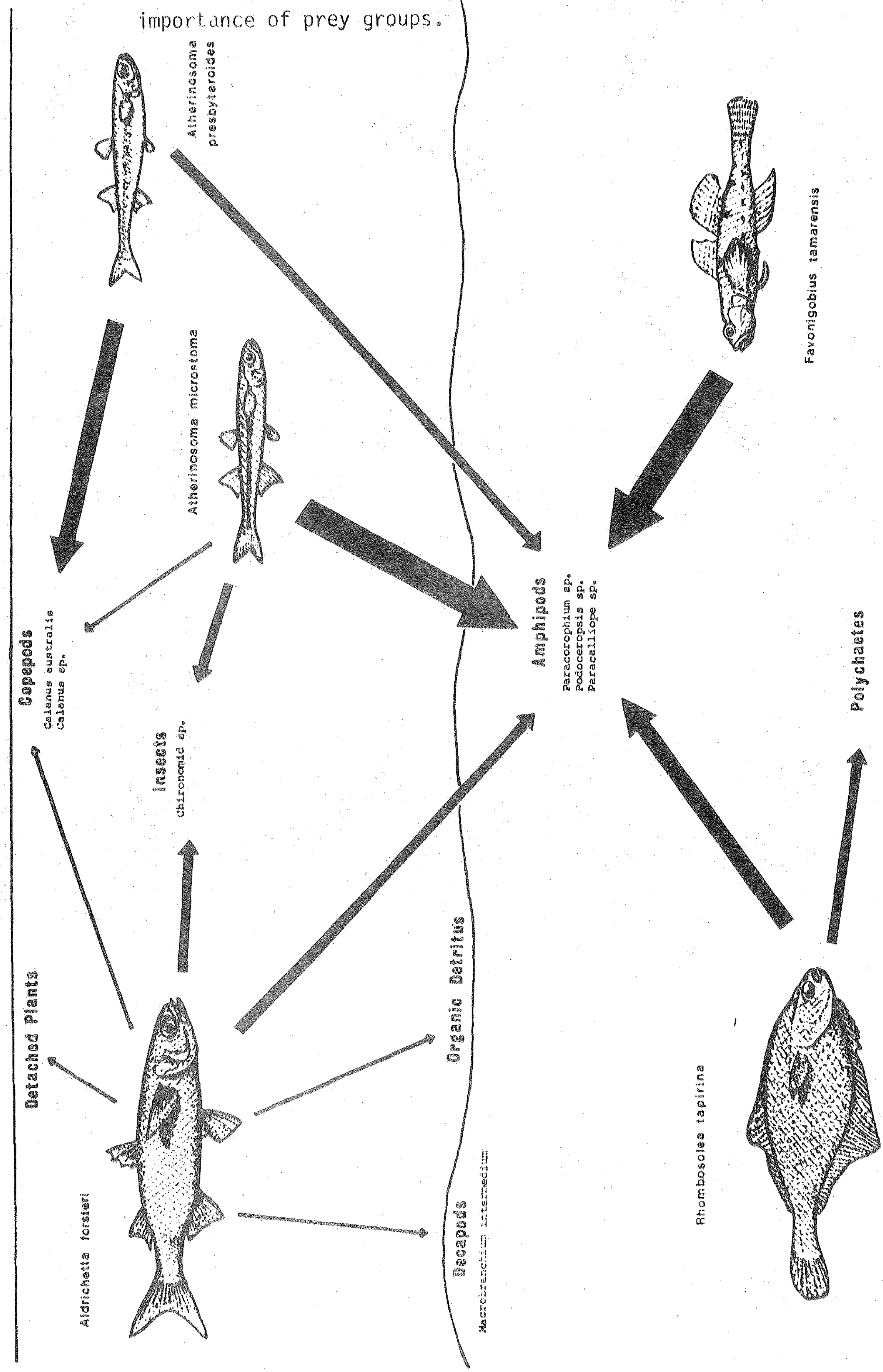


Fig. 6:30. Food relationships of fishes at a sparsely vegetated site in the middle estuary (site 5). Arrow widths indicate the importance of prey groups.



planktivores. A difference in diet between *Ammotretis rostratus* and the other benthic grazers was evident also from the similarity matrix (Appendix 6:4) but this should be more valid because the sample size was larger.

A summary of the food web at this site is provided in Figure 6:29.

Site 5

The most abundant species at this sandy site were clustered into two broad ecological categories: benthic carnivores and pickers (Fig. 6:19, 24).

Amphipods were major food components of the benthic species *Rhombosolea tapirina* and *Favonigobius tamarensis*. A similarly large proportion of amphipods in the stomach contents of the planktivore, *Atherinosoma microstoma*, probably accounted for its high similarity to the benthic species (Appendix 6:4). The remaining midwater feeders, *Hyporhamphus melanochir*, *Atherinosoma presbyteroides* and *Aldrichetta forsteri* ate much smaller quantities of amphipods; seagrasses, copepods and insects respectively were the major components for these species.

The total food habit of fishes at this site (see Fig. 6:13b) was essentially similar to site 4 except that the insect component of the former was proportionally larger and the polychaete and ascidian elements smaller.

A dendogram (Fig. 6:28a) based on prey species presence/absence data indicated, for the fish species, similar dietary trends to those exhibited at site 4 (Fig. 6:27d). The omnivore, *Hyporhamphus melanochir*, was shown to be least similar to the benthic carnivores and planktivores (Appendix 6:4).

The food relationships at this site are summarised in Figure 6:30.

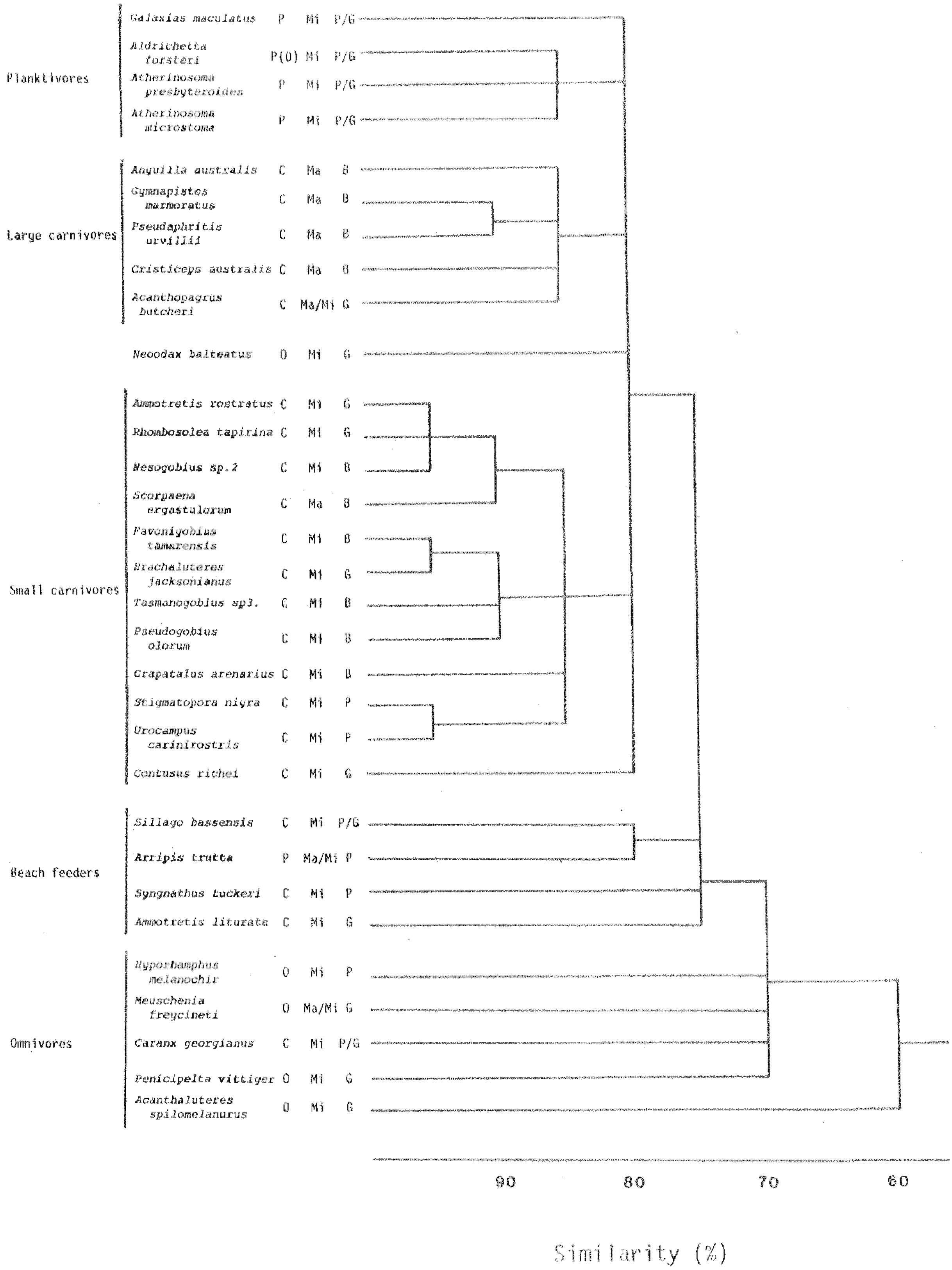
Site 6

Food habit relationships, as depicted by the cluster analysis of major prey groups, were difficult to interpret (Fig. 6:19, 25). Several main aggregations were defined but these proved useless in highlighting species with similar feeding habits. The major dietary associations were as follows: *Atherinosoma microstoma* and the microphagous benthic species, *Rhombosolea tapirina* and *Pseudogobius olorum*, preyed mainly on amphipods; *Atherinosoma presbyteroides* and the pipefishes, *Stigmatopora nigra* and *Urocampus carinirostris*, on copepods; *Galaxias maculatus* and *Aldrichetta forsteri* on insects; macrophagous carnivores, *Pseudaphritis urvillii* and *Gymnapistes marmoratus*, on decapod crustaceans; and omnivores, *Neoodax balteatus* on decapods and *Meuschenia freycineti* on seagrass. Individually, these major prey groups occupied over 50% of the diets of 6 species; *Rhombosolea tapirina*, *Pseudaphritis urvillii*, *Pseudogobius olorum*, *Atherinosoma microstoma* and the pipefishes.

Insects were also consumed in substantial amounts by benthic species such as *Rhombosolea tapirina* and *Pseudogobius olorum*. The insects involved were chironomids or midges, the larvae of which metamorphose on the bottom and then migrate to the surface (McQuillan, personal communication). During this period, which is mainly late winter to early spring, they are important food items for predatory fishes.

Crustaceans contributed to approximately 65% of the total diet of fishes at this site (see Fig. 6:13b) and the overall proportional representation of dietary items most closely resembled site 5. Isopods and decapods appeared to be more abundant among the seagrass, which was denser at this site than at the lower estuary sites sampled.

A cluster analysis based on prey species (Fig. 6:28) lumped the dominant planktivores (*Aldrichetta forsteri*, *Atherinosoma microstoma* and *Atherinosoma presbyteroides*), the macrophagous carnivores (*Gymnapistes marmoratus* and *Pseudaphritis urvillii*) and the omnivores (monacanthid species) into aggregates. A close similarity between *Galaxias maculatus* and *Pseudogobius olorum* was evident.


Planktivores
Galaxias maculatus P Mi P/G
Aldrichetta forsteri P(O) Mi P/G
Atherinosoma presbyteroides P Mi P/G
Atherinosoma microstoma P Mi P/G
Large carnivores
Anguilla australis C Ma B
Gymnapistes marmoratus C Ma B
Pseudaphritis urvillii C Ma B
Cristiceps australis C Ma B
Acanthopagrus butcheri C Ma/Mi G
Neoodax balteatus O Mi G
Small carnivores
Ammotretis rostratus C Mi G
Rhombosolea tapirina C Mi G
Nesogobius sp.2 C Mi B
Scorpaena ergastulorum C Ma B
Favonigobius tamarensis C Mi B
Brachaluteres jacksonianus C Mi G
Tasmanogobius sp3. C Mi B
Pseudogobius olorum C Mi B
Crapatalus arenarius C Mi B
Stigmatopora nigra C Mi P
Urocampus carinirostris C Mi P
Contusus richei C Mi G
Beach feeders
Sillago bassensis C Mi P/G
Arripis trutta P Ma/Mi P
Syngnathus tuckeri C Mi P
Ammotretis liturata C Mi G
Omnivores
Hyporhamphus melanochir O Mi P
Meuschenia freycineti O Ma/Mi G
Caranx georgianus C Mi P/G
Penicipelta vittiger O Mi G
Acanthaluteres spilomelanurus O Mi G
90
80
70
60
Similarity (%)

Relationships within Guilds

The relationships between food habits of related species was further examined by cluster analyses of the 3 guilds. The species groups selected included representatives of the most diverse or numerically abundant families which characterised one of the major guilds.

These species groups were as follows:

(1) Flounders (grazers) - *Ammotretis rostratus*, *A. liturata* and *Rhombosolea tapirina* ;

(2) Gobies (browsers) - *Favonigobius tamarensis*, *Nesogobius* sp. 2 and *Pseudogobius olorum*;

(3) Dominant planktivores (mainly pickers) - *Aldrichetta forsteri*, *Atherinosoma microstoma*, *A. presbyteroides* and *Arripis trutta*.

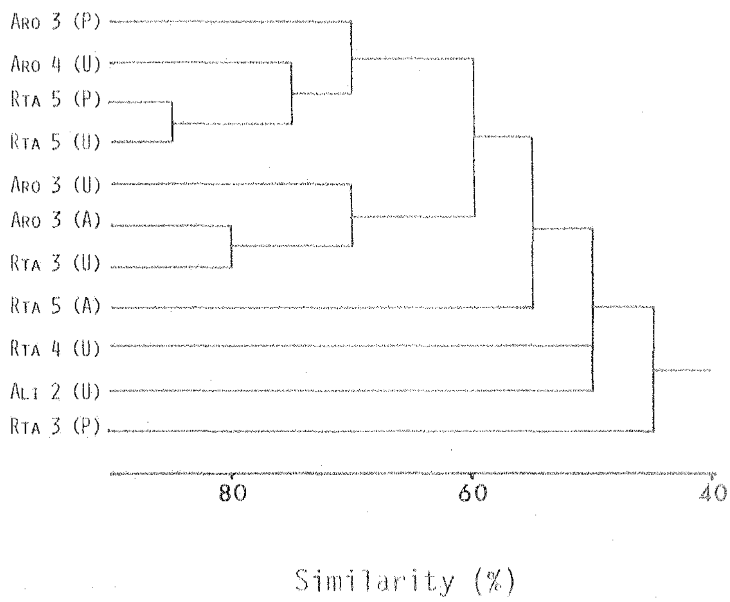
Groups to be clustered were based on site number and season, and only those containing contents from more than 15 individuals of a species were included in the analysis; a group containing 9 replicates of *Pseudogobius olorum* was the only exception. Ontogenetic differences in diets were minimized by deleting data from individuals larger than 15 cm. This size class was likely to have the greatest feeding overlap because it contained the largest numbers of individuals in each guild.

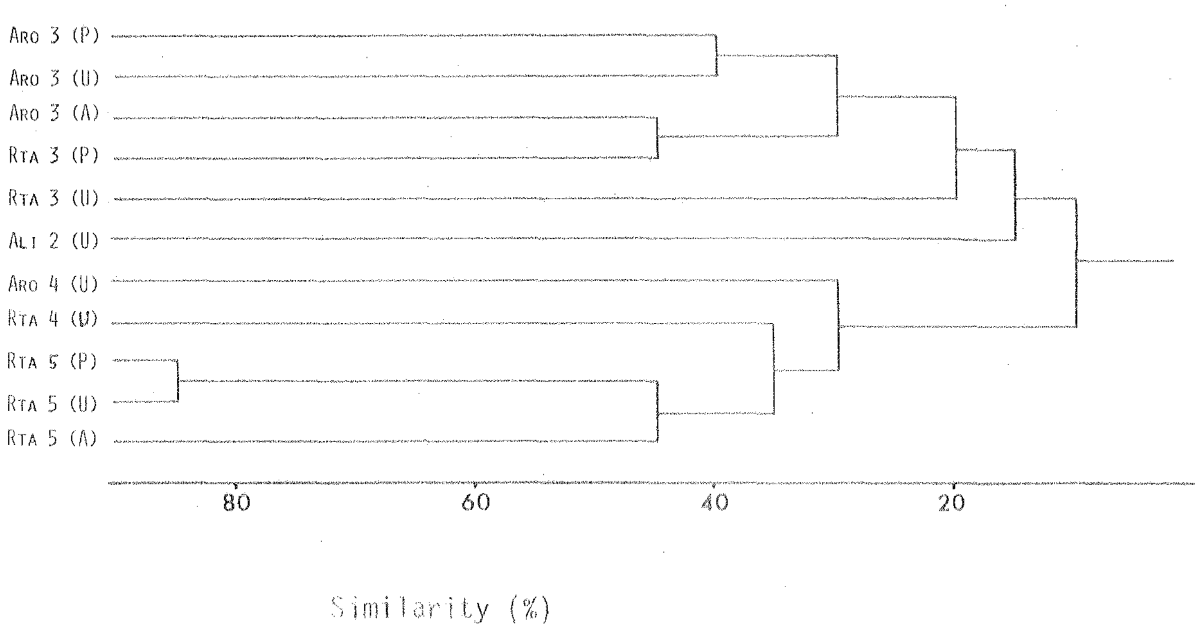
Grazers

A dendogram of similarity between the 3 species, based on prey groups, provided a poor ordination of species, sites and seasonal groups (Fig. 6:34). The similarity matrix (Appendix 6:5) clearly showed that most groups were of similar magnitude with none markedly dissimilar from the rest. These finds suggest that the flatfish species exploit similar prey groups.

Fig. 6:34. Dendrogram of similarity for centroid cluster analysis of the diets of grazers (Ali, *Ammotretis liturata;* Aro, *Ammotretis rostratus;* and Rta, *Rhombosolea tapirina*) at sites 2 - 6 based on prey groups. A, autumn. U, summer. P, spring.

Fig. 6:35. Dendrogram of similarity for centroid cluster analysis of the diets of grazers (Ali, *Ammotretis liturata;* Aro, *Ammotretis rostratus;* and Rta, *Rhombosolea tapirina*).at sites 2 - 6 based on prey species. A, autumn. U, summer. P, spring.


Aro 3 (P)
Aro 4 (U)
Rta 5 (P)
Rta 5 (U)
Aro 3 (U)
Aro 3 (A)
Rta 3 (U)
Rta 5 (A)
Rta 4 (U)
Ali 2 (U)
Rta 3 (P)
80
60
40
Similarity (%)


Aro 3 (P)
Aro 3 (U)
Aro 3 (A)
Rta 3 (P)
Rta 3 (U)
Ali 2 (U)
Aro 4 (U)
Rta 4 (U)
Rta 5 (P)
Rta 5 (U)
Rta 5 (A)
80
60
40
20
Similarity (%)

Cluster analysis of the flatfish groups, based on the occurrence of prey species, classified the diets of species, firstly on site number and secondly on species (Fig. 6:35). Unlike the analysis based on prey group, the dendogram shapes of both centroid and furthest neighbour analyses based on prey species, were identical.

Food habits of *Rhombosolea tapirina* and *Ammotretis rostratus* at sites 5 and 6 were different from those at the estuary mouth (site 3). *A. liturata* at site 2 was distinct from other species but showed the closest affinity to site 3 groups. Differences in diet between flatfishes from site 2 and site 4 were apparent from the zero values in the similarity matrix (Appendix 6:5).

More subtle secondary trends were evident between *R. tapirina* and *A. rostratus* at sites 3 and 4. *R. tapirina* from site 4 was more similar to both site 3 *R. tapirina* groups than to any of the *A. rostratus* groups from site 3. Conversely, *A. rostratus* from site 4 was more similar to *A. rostratus* groups than to *R. tapirina* groups from site 3.

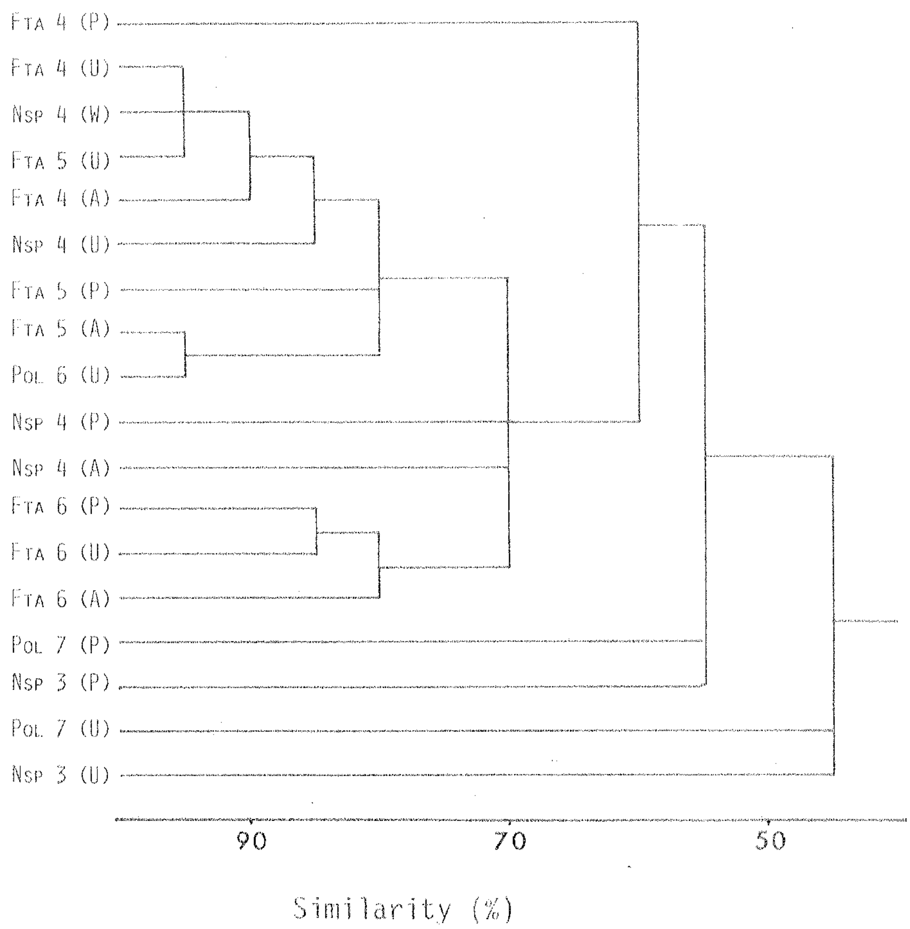
In summary, the flounder species appeared to feed on similar prey groups but selected different prey species at each area of the estuary. Although the types of food selected by sympatric species at one area were similar, subtle prey selection differences were apparent.

Browsers

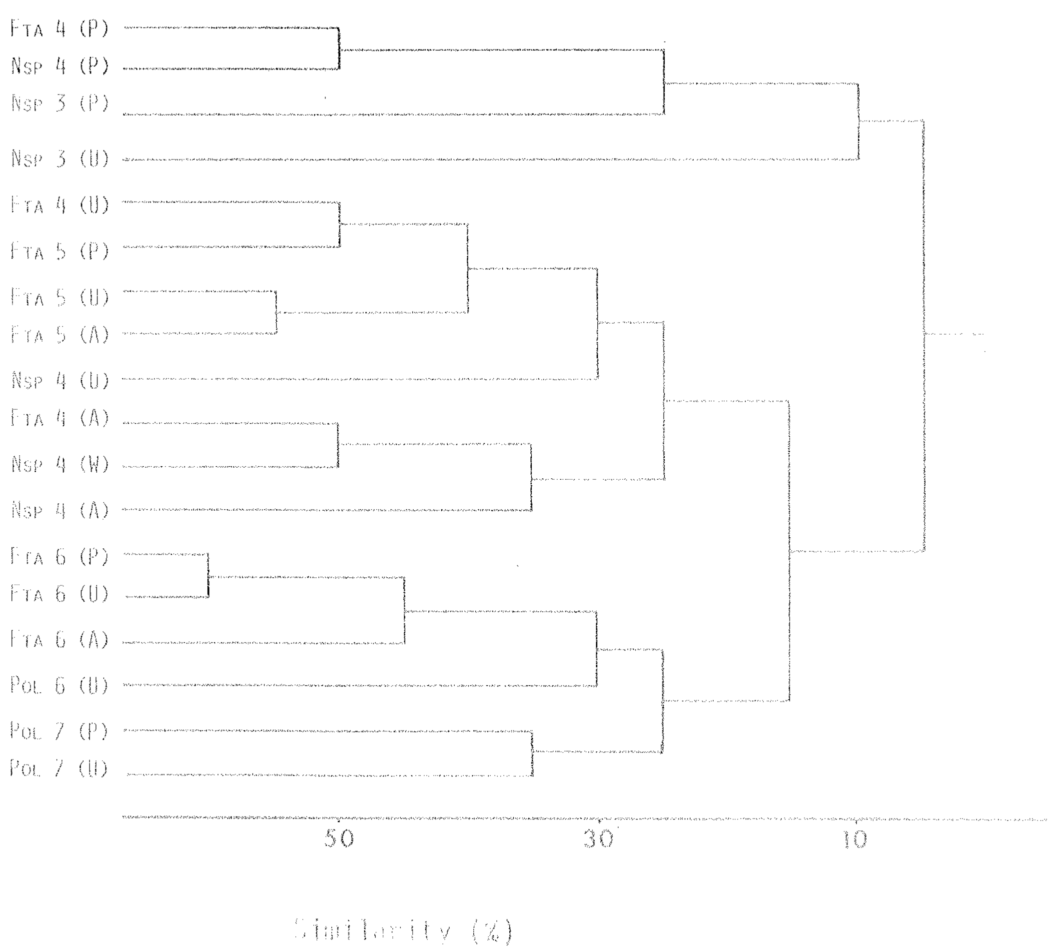
Cluster analysis of 18 groups representing food habits of the 3 goby species, based on major prey groups, provided weak trends between sites (Fig. 6:36). Food components of species from either end of the estuary (sites 3 and 7) differed from the other intermediate sites. Although *Nesogobius* sp. 2 and *Pseudogobius olorum* from sites 3 and 7 respectively were grouped near each other, they were not similar (Appendix 6:5).

Fig. 6:36. Dendrogram of similarity for centroid cluster analysis of the diets of browsers (Fta, *Favonigobius tamarensis;* Nsp, *Nesogobius* sp. 2; and Pol, *Pseudogobius olorum*) at sites 3 - 7 based on prey groups. A, autumn. P, spring. U, summer. W, winter.

Fig. 6:37. Dendrogram of similarity for centroid cluster analysis of the diets of browsers (Fta, *Favonigobius tamarensis;* Nsp, *Nesogobius* sp. 2; and Pol, *Pseudogobius olorum*) at sites 3 - 7 based on prey species. A, autumn. P, spring. U, summer. W, winter.



FTA 4 (P)
FTA 4 (U)
NSP 4 (W)
FTA 5 (U)
FTA 4 (A)
NSP 4 (U)
FTA 5 (P)
FTA 5 (A)
POL 6 (U)
NSP 4 (P)
NSP 4 (A)
FTA 6 (P)
FTA 6 (U)
FTA 6 (A)
POL 7 (P)
NSP 3 (P)
POL 7 (U)
NSP 3 (U)
90
70
50
Similarity (%)



FTA 4 (P)
NSP 4 (P)
NSP 3 (P)
NSP 3 (U)
FTA 4 (U)
FTA 5 (P)
FTA 5 (U)
FTA 5 (A)
NSP 4 (U)
FTA 4 (A)
NSP 4 (W)
NSP 4 (A)
FTA 6 (P)
FTA 6 (U)
FTA 6 (A)
POL 6 (U)
POL 7 (P)
POL 7 (U)
50
30
10
Similarity (%)

Differences in prey selection at the intermediate sites 4, 5 and 6 were not clearly distinguishable, although *Favonigobius tamarensis* at site 6 appeared to have a characteristic food habit.

Cluster analysis based on prey species, yielded a clustering of these groups into 3 branches (Fig. 6:37). The first branch consisted of site 3 groups of *N.* sp. 2 and two site 4 groups of *N.* sp. 2 and *F. tamarensis* from spring. The spring sample from site 3 was most similar to the site 4 groups which suggested that unique prey characteristics may have been present during spring. The second branch provided, with one exception, a separation of site 5 groups and the remaining site 4 groups and subsequently discriminated between *N.* sp. 2 and *F. tamarensis* at these sites.

In the final branch, site 7 groups were segregated from those at site 6. For example, *P. olorum* from site 6 was lumped with *F. tamarensis* groups from that site and not with replicate groups from site 7.

Pickers

Each of the 4 species, *Atherinosoma microstoma, A. presbyteroides, Aldrichetta forsteri* and *Arripis trutta,* exhibited some distinctiveness of food habit based on major prey components (Fig. 6:38). While *Arripis trutta* and *Atherinosoma microstoma* groups were most distinct, *Aldrichetta forsteri* and *Atherinosoma presbyteroides* exhibited greatest overlap in food habits.

Two major clusters were identified by the analysis. The largest group (uppermost in Fig. 6.38) mainly isolated *A. forsteri* and *A. presbyteroides* site groups which included 94% and 92% respectively of the total number of site groups for these species. The other group gave indications of a food overlap between *A. trutta* and *A. microstoma;* in this case 67% and 87% respectively of the total number of site groups for these species were clustered in this group. Site and seasonal trends were not evident.

Fig. 6:38. Dendrogram of similarity for centroid cluster analysis of the diets of pickers (Afo, *Aldrichetta forsteri;* Ami, *Atherinosoma microstoma;* Aps, *Atherinosoma presbyteroides;* and Atu, *Arripis trutta*) at sites 2 - 7 based on prey groups. A, autumn. P, spring. U, summer. W, winter.

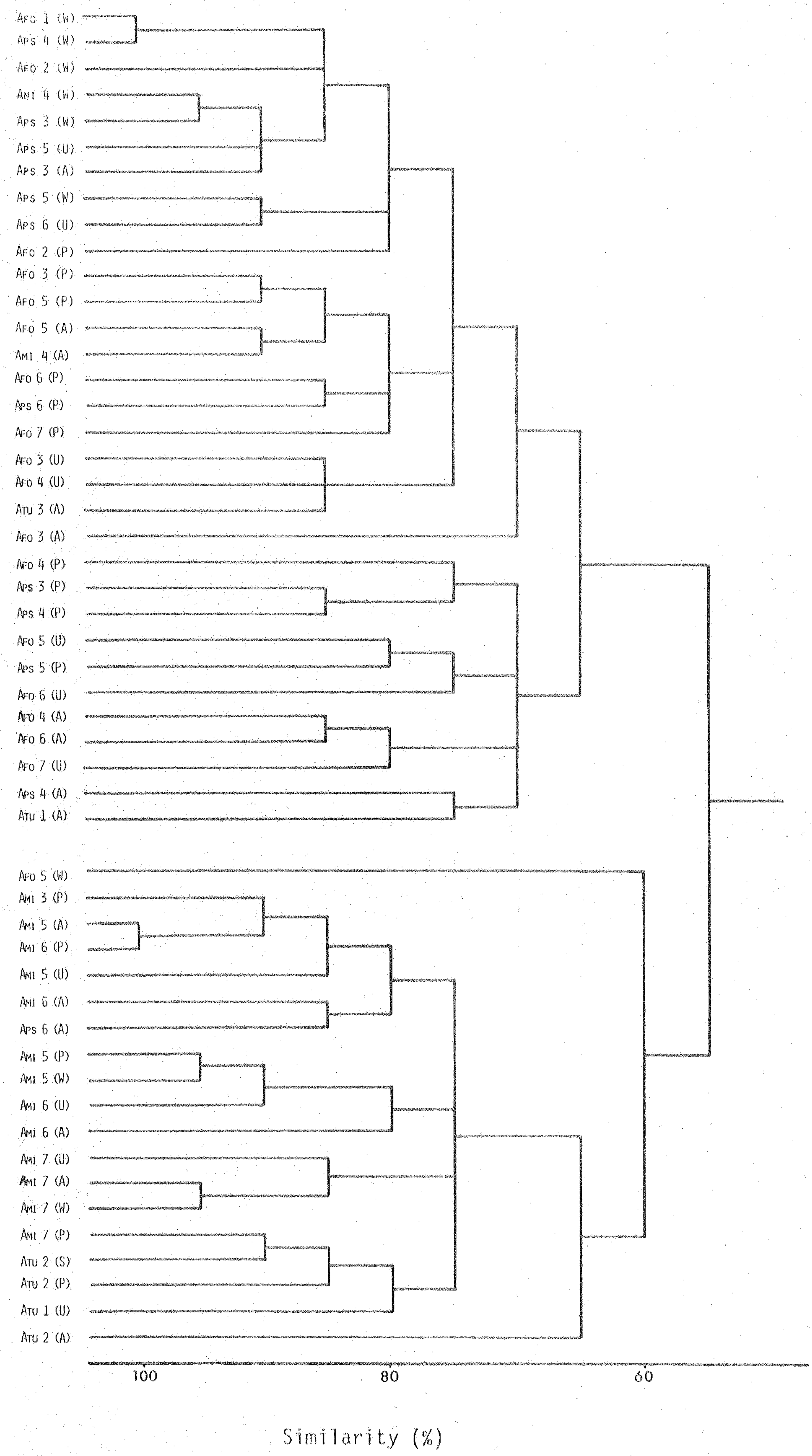
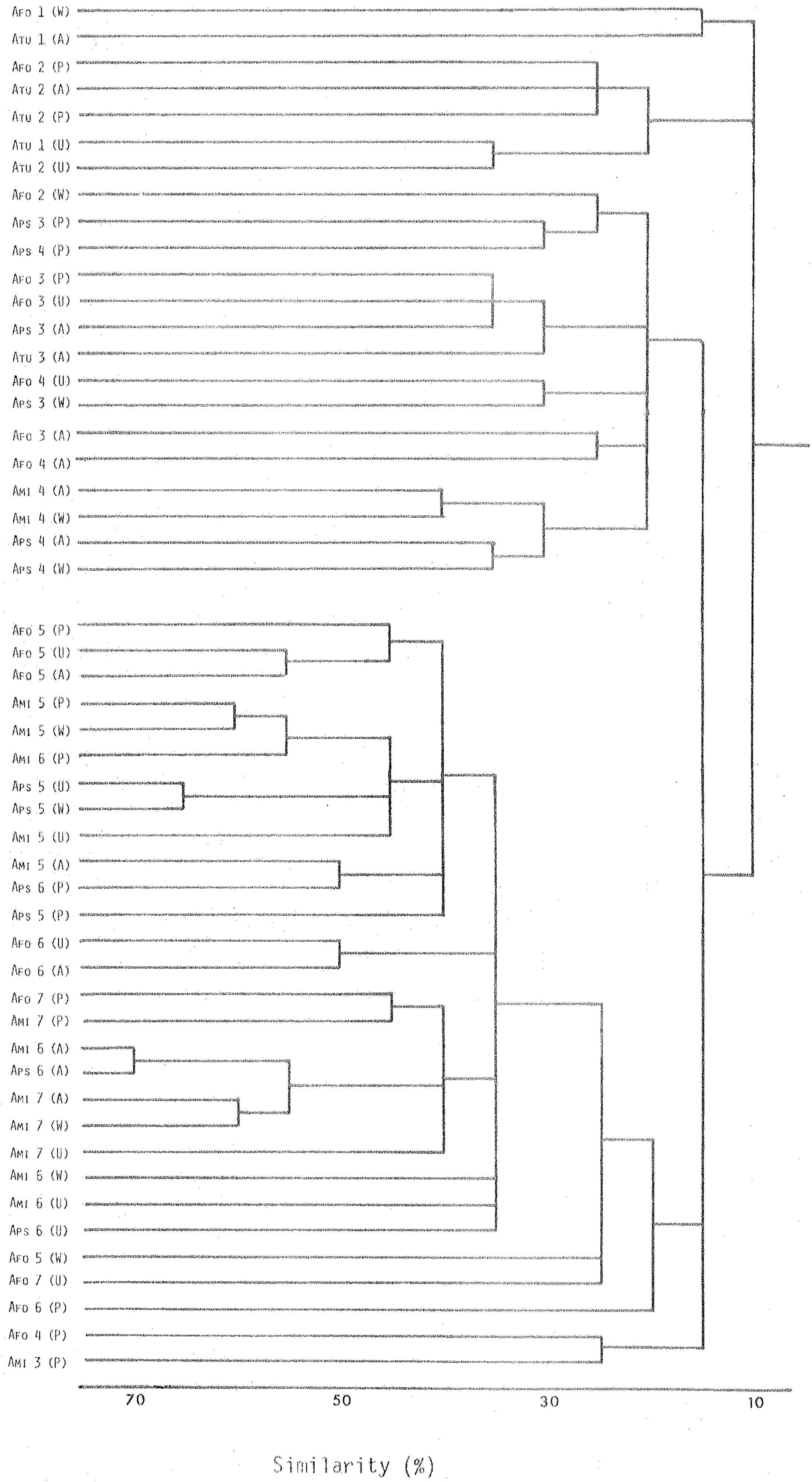

AFO 1 (W)
APS 4 (W)
AFO 2 (W)
AMI 4 (W)
APS 3 (W)
APS 5 (U)
APS 3 (A)
APS 5 (W)
APS 6 (U)
AFO 2 (P)
AFO 3 (P)
AFO 5 (P)
AFO 5 (A)
AMI 4 (A)
AFO 6 (P)
APS 6 (P)
AFO 7 (P)
AFO 3 (U)
AFO 4 (U)
ATU 3 (A)
AFO 3 (A)
AFO 4 (P)
APS 3 (P)
APS 4 (P)
AFO 5 (U)
APS 5 (P)
AFO 6 (U)
AFO 4 (A)
AFO 6 (A)
AFO 7 (U)
APS 4 (A)
ATU 1 (A)
AFO 5 (W)
AMI 3 (P)
AMI 5 (A)
AMI 6 (P)
AMI 5 (U)
AMI 6 (A)
APS 6 (A)
AMI 5 (P)
AMI 5 (W)
AMI 6 (U)
AMI 6 (A)
AMI 7 (U)
AMI 7 (A)
AMI 7 (W)
AMI 7 (P)
ATU 2 (S)
ATU 2 (P)
ATU 1 (U)
ATU 2 (A)
100
80
60
Similarity (%)

Fig. 6:39. Dendrogram of similarity for centroid cluster analysis of the diets of pickers (Afo, *Aldrichetta forsteri;* Ami, *Atherinosoma microstoma;* Aps, *Atherinosoma presbyteroides;* and Atu, *Arripis trutta)* at sites 2 - 7 based on prey species. A, autumn. P, spring. U, summer. W, winter.


Afo 1 (W)
Atu 1 (A)
Afo 2 (P)
Atu 2 (A)
Atu 2 (P)
Atu 1 (U)
Atu 2 (U)
Afo 2 (W)
Aps 3 (P)
Aps 4 (P)
Afo 3 (P)
Afo 3 (U)
Aps 3 (A)
Atu 3 (A)
Afo 4 (U)
Aps 3 (W)
Afo 3 (A)
Afo 4 (A)
Ami 4 (A)
Ami 4 (W)
Aps 4 (A)
Aps 4 (W)
Afo 5 (P)
Afo 5 (U)
Afo 5 (A)
Ami 5 (P)
Ami 5 (W)
Ami 6 (P)
Aps 5 (U)
Aps 5 (W)
Ami 5 (U)
Ami 5 (A)
Aps 6 (P)
Aps 5 (P)
Afo 6 (U)
Afo 6 (A)
Afo 7 (P)
Ami 7 (P)
Ami 6 (A)
Aps 6 (A)
Ami 7 (A)
Ami 7 (W)
Ami 7 (U)
Ami 6 (W)
Ami 6 (U)
Aps 6 (U)
Afo 5 (W)
Afo 7 (U)
Afo 6 (P)
Afo 4 (P)
Ami 3 (P)
70
50
30
10
Similarity (%)

A dendogram, produced from analysis of the fish species groups based on prey species, provided a good separation of groups according to site (Fig. 6:39). The major branches were separated in accordance with the fish community types discussed earlier (see Section 6:5). These included species feeding (1) at beach sites 1 and 2 (*Arripis trutta, Aldrichetta forsteri*), (2) at lower estuary sites 3 and 4 (all 4 species) and (3) middle and upper estuary sites 4 and 5 (*Aldrichetta forsteri, Atherinosoma microstoma, Atherinosoma presbyteroides*). Two site groups from the lower estuary were not grouped into any of the above. Further separation of sites, particularly between site 5 and sites 6 and 7, within branches was also apparent.

Conspecific groups from each site were often closely associated within branches and some seasonal relationships were evident for spring and autumn groups.

6:7 DISCUSSION AND CONCLUSIONS

The Great Swanport Estuary has physical and biological characteristics that are distinctive of open lagoons in the Tasmanian region. It is permanently open to the sea, is mostly shallower than 4 m, is predominantly polyhaline or euhaline and has dense stands of seagrasses and brackish plants.

Fifty-nine percent of the fish species collected from open lagoons (see Chapter 4) were recorded from the Great Swanport Estuary. This fauna can be grouped into 2 broad associations, an assemblage in the upper and middle estuary and an assemblage in the lower estuary. These associations have few species that are unique to either but instead have several species that exhibit a preference for one over the other. Overlap between the assemblages is compounded by a few abundant widespread species. Furthermore, distributions of species appeared to be altered by reproductive and behavioural patterns and changes in the physical conditions within the estuary.

Nine Mile Beach, a typical semi-exposed beach, has a distinct fish fauna which also contains a small element of widespread species occurring in the estuary. Of these, only *Aldrichetta forsteri* and *Arripis trutta* are abundant throughout these habitats. Harris (1968) has stated that juvenile *Aldrichetta forsteri* is restricted to shallow estuaries or sheltered embayments but accumulations of detached plant material provide an alternative habitat on exposed beaches (Lenanton, Robertson and Hansen, 1982). The occurrence of *Aldrichetta forsteri* in samples from Nine Mile Beach coincided with calm periods. Thus, wave climates could be important in controlling the abundances of mobile sheltered beach and estuarine fishes in exposed beach habitats.

The beach acts as a breeding ground and nursery ground for few species. Despite its comparatively depauperate fauna, 2 species apparently using this habitat as a major nursery area, *Arripis trutta* and *Ammotretis liturata*, are important commercially in this region.

Food habit data was presented in a generalised form to determine the overall structure of higher trophic levels and did not account for temporal or ontogenetic variations in diet. De Sylva (1975) has stated that seasonal or yearly changes are most apparent in high latitudes whilst Helfman (1978) has claimed that there may be less overlap on an intraspecific than on an interspecific basis. Such trends, along with diel changes in diet, were apparent for some species but these require lengthly discussion and will not be presented herein.

Data from the gut content analyses demonstrated patterns of habitat usage in which most fish species acted as primary carnivores, feeding mainly on amphipods. De Sylva (1975) has reviewed studies of food habits and food webs of estuarine nekton. He proposed a classification of nektonic food webs in estuaries based mainly on phytoplankton or detritus and provided examples of each type. Of the types described, the food web of the Knysna Estuary, South Africa (Day, 1967) most clearly resembles the situation found in the Great Swanport Estuary. In the former, relationships appear to be less complex but both estuaries have a predominance of primary carnivores with few detritivores or secondary carnivores. These food webs utilise plankton and detritus as energy sources but the main planktivores and detritivores appear to be invertebrates rather than fishes. The role of invertebrates needs to be qualified, however, as there have been no feeding studies of invertebrates in Tasmanian estuaries.

Fishes living in the estuary and on the beach displayed facultative feeding behaviour, although some species were more generalised feeders than others. Greatest food overlap occurred between species with similar feeding strategies. This overlap was evident from data on total dietary compositions based on prey groups and from within-sites prey groups and prey species data. Most species were opportunistic at each site and their food habits varied between sites, probably in response to the availability of prey. For each guild, interspecifics within-sites were more similar in diet, particularly based on prey species, than were intraspecifics between-sites.

Similarity in the diets of fishes was also examined using the widely used Spearman rank correlation coefficient (Fritz, 1974) but, as this has since been shown to be a poor measure of similarity (Wallace, 1981), the results were not presented.

CHAPTER 7

ZOOGEOGRAPHY

7:1 INTRODUCTION

Marine zoogeography is characterised by three aims (Briggs,1974): namely to delineate and characterise distinct faunal areas; to trace the history of faunas; and to use these data in support of evolutionary information. McDowall (1978) has criticised the validity of Briggs' attempt to define faunal provinces, opting instead for an examination of the dynamics of the fauna through its relationships, derivations and speciation patterns. Nevertheless, a broad classification of oceans into major regions is useful in examining latitudinal zonation, horizontal dispersal and resemblances and contrasts of regional communities.

In discussing the zoogeographical characteristics of a fauna in a given area, two aspects should be considered: firstly, to examine the distributions of species in that area and secondly, to relate their distributions to adjacent areas.

The distribution of marine animals is largely disjunct, depending greatly on the availability of suitable habitats (Pielou, 1979). Therefore an intra-regional comparison of assemblages, representing a single community type, should provide a better appraisal of faunal differences within that region than a broad comparison of mixed communities. For example, habitats devoid of seagrasses are not normally occupied by fishes that typify vegetated habitats. Consequently, the characteristics of these fish species are, to some extent, determined by the distributions of seagrasses.

Studies of the distributions of fishes in most parts of the Southern Hemisphere have, until recently, been scant. Mead (1970) stated that the fish fauna of the South Pacific harboured the least known fish fauna in the oceans. McDowall (1978) has given examples of recently first recorded New Zealand fishes becoming major fisheries resources in that area. A similar situation exists off southern Australia where major commercial fishes, the king dory (*Cyttus traversi*) and orange roughy (*Hoplostethus atlanticus*), were first recorded only recently (Last and Harris, 1981; Wilson, 1982). This paucity of knowledge has not been restricted to deepsea environments. Several coastal reef fish, which because of insufficient collecting were considered to be rare, now appear to be common off Tasmania. Recent studies that have just been completed or are currently in progress have contributed much to the knowledge of fish faunas in this region.

The most recent published checklist of 264 Tasmanian fishes was compiled by Lord and Scott (1924). Important recent additions to this list, other than those presented in earlier sections of the study, have been made from rocky reef surveys (Edgar, 1981; Hutchins, unpublished data), several deep water trawl surveys (Last and Harris, 1981; Collins and Baron, 1981; Wilson, unpublished data) and a series of descriptive papers by Scott (1934 - 82).

An updated and annotated checklist comprising about 550 species has now been constructed (Last, in preparation). The completeness of check-lists, particularly of marine organisms, is usually difficult to assess, but it is unlikely that the Tasmanian fauna contains more than 600 species. Few species may still remain undetected from freshwater and shallow reef habitats but the lower continental shelf and the midwater oceanic zone have been poorly sampled and many unrecorded species may frequent these habitats.

In this chapter, the intra-regional distributions of the shore zone fish fauna are examined and the wider inter-regional relationships of the estuarine fauna are explored. Endemism in the Tasmanian fish fauna is also discussed.

7:2 METHODS

Zoogeographic relationships of fishes were examined using computer assisted centroid and furthest neighbour cluster analyses provided in a GENSTAT package (Alvey *et al.*, 1977). This technique, in which matching zeros were deleted, has been outlined in Section 4:2.

The data input consisted of presence/absence information on the occurrence of species at various habitat types used in Section 4:4 within each of the 16 coastal regions discussed in Section 4:3:4. Habitat types, which were considered to contain characteristic faunas (see Fig. 4:16b), were analysed separately and included closed systems, tidal rivers, open lagoons/bay estuaries, sheltered beaches and exposed beaches. Only coastal regions with more than 5 replicates of a habitat type were included in the analysis of the type.

Cluster analyses were also used to examine the faunal relationships of estuarine fishes from some other temperate regions defined by Briggs (1974). Data were extracted from several faunal works undertaken in the other regions. These included studies on estuarine faunas of the British Isles (Wheeler, 1969; van den Broek, 1979), western U.S.A. (Horn and Allen, 1976 ancilliary data), eastern U.S.A. (de Sylva, Kalber and Shuster, 1962), South Africa (Wallace, 1975a), Japan (Ueno, 1971) and New Zealand (Webb, 1972, 73b; Kilner and Ackroyd, 1978). Additional data from studies of Australian temperate estuarine fishes were obtained from New South Wales (Bell, 1980), Victoria (Rigby, 1979) and Western Australia (Chubb *et al.*, 1979; Lenanton, 1974, 77). In each case the presence of a fish family was recorded following the systematic list recommended by Nelson (1976); information on regional endemics was obtained largely from this source. Because the primary aim of these analyses was to determine levels of similarity between faunas rather than to examine the degree of family endemism within provinces, they were repeated with endemic families removed. Faunal lists for Victoria and New Zealand were based on less comprehensive studies so the data were re-analysed with these omitted.

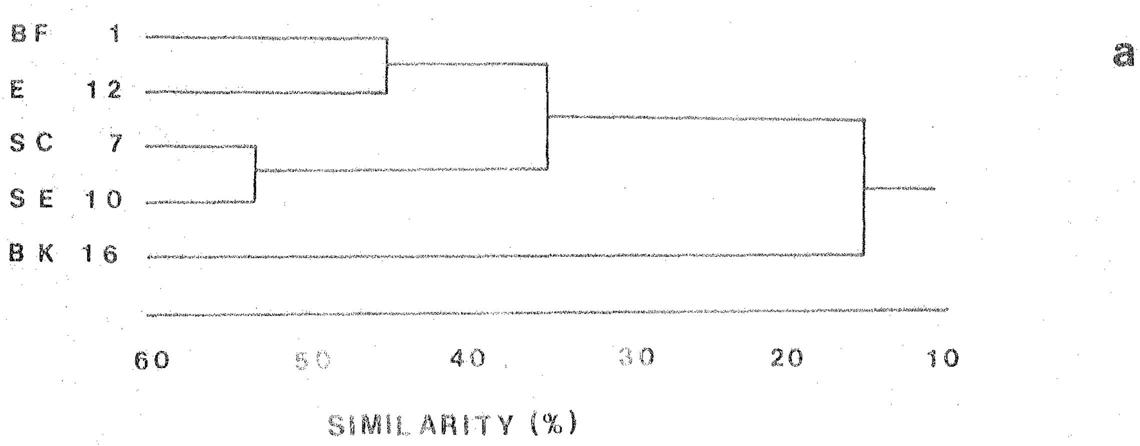
Distributions of most shore zone fishes collected in this study are provided in Appendix 7:1.

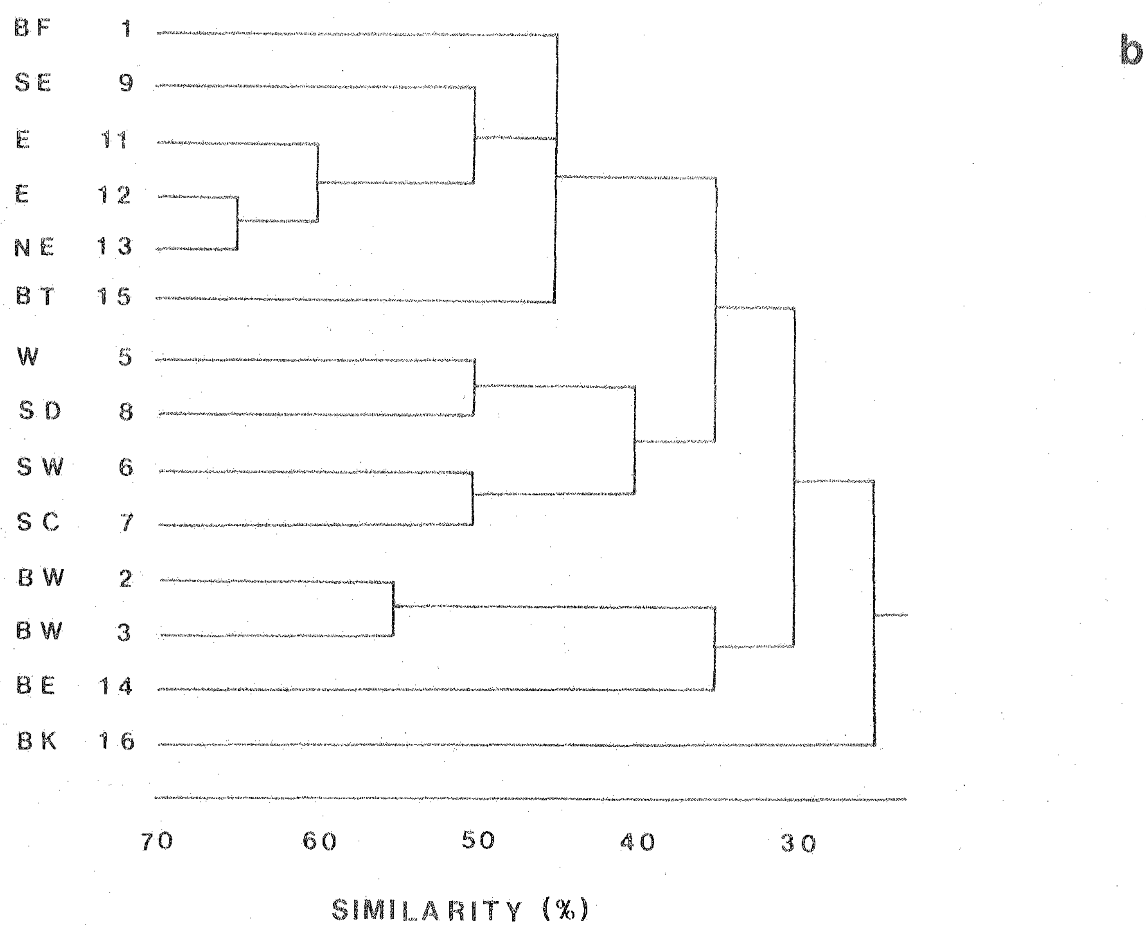
7:3 DISTRIBUTIONAL FEATURES OF TASMANIAN SHORE ZONE FISHES IN SEDIMENTARY HABITATS.

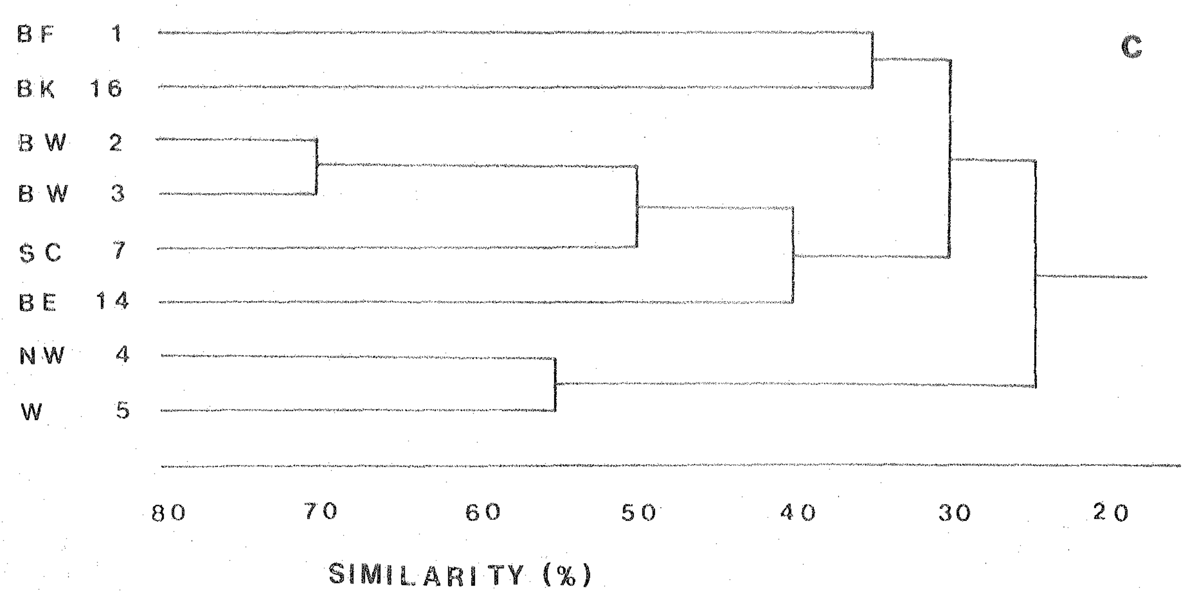
7:3:1 Regional Distributions of Communities

The fauna of closed systems appeared to exhibit some compositional differences between the 5 coastal regions having sufficient replicates to be included in a centroid cluster analysis (Fig. 7:1a). Northeastern regions, 'Furneaux Group' (region 1) and 'northern East Coast' (region 12), were aggregated together while southeastern regions, 'D'Entrecasteaux Channel' (region 7) and 'Peninsula' (region 10), were also most similar. The fauna of closed systems on King Island (region 16) appeared to be distinct. Adjacent regions exhibited the highest similarities and 'King Island' was least similar to all other regions (Appendix 7:2). This trend is probably not latitudinal, but is instead determined through habitat

Fig. 7:1. Dendrograms showing levels of similarity of fish assemblages between coastal regions (1 - 16) in the following habitat types: (a) closed systems; (b) bay estuaries and open lagoons; and (c) tidal rivers and creeks. Coastal regions follow those outlined in Section 4:3:4. (1, BF) Furneaux Group. (2, BW) North Coast. (3, BW) Western North Coast. (4, NW) Northern West Coast. (5, W) West Coast. (6, SW) South-West Coast. (7, SC) D'Entrecasteaux Channel. (8, SD) Derwent Estuary. (9, SE) South-East Bays. (10, SE) Peninsula. (11, E) East Coast. (12, E) Northern East Coast. (13, NE) North-East Coast. (14, BE) Eastern North Coast. (15, BT) Tamar River. (16, BK) King Island.


a
BF 1
E 12
SC 7
SE 10
BK 16
60
50
40
30
20
10
SIMILARITY (%)


b
BF 1
SE 9
E 11
E 12
NE 13
BT 15
W 5
SD 8
SW 6
SC 7
BW 2
BW 3
BE 14
BK 16
70
60
50
40
30
SIMILARITY (%)

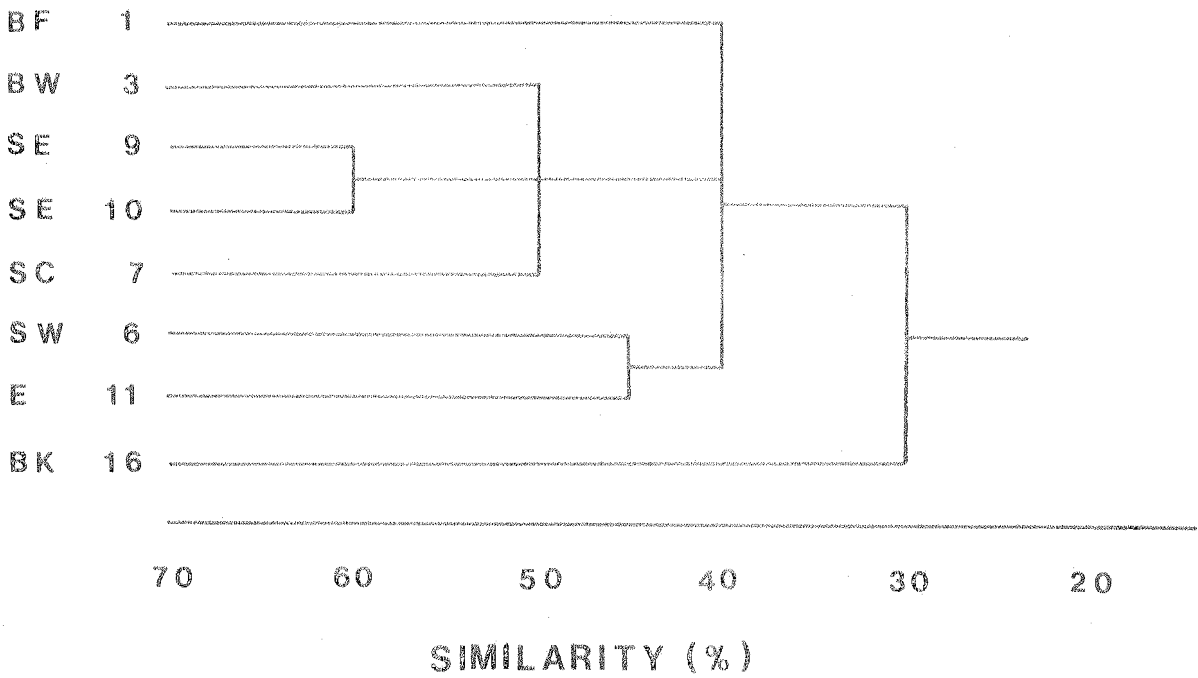

c
BF 1
BK 16
BW 2
BW 3
SC 7
BE 14
NW 4
W 5
80
70
60
50
40
30
20
SIMILARITY (%)

variation in the physical characteristics of habitats. Closed systems in the northeastern areas of Tasmania are predominantly polyhaline or euhaline and appear to contain more diverse faunas (15 - 16 species) than do the oligohaline-freshwater dune lakes and beach-dammed rivers of King Island (5 species). The basins in southeastern Tasmania have similar characteristics (8 species) to those of the North-East.

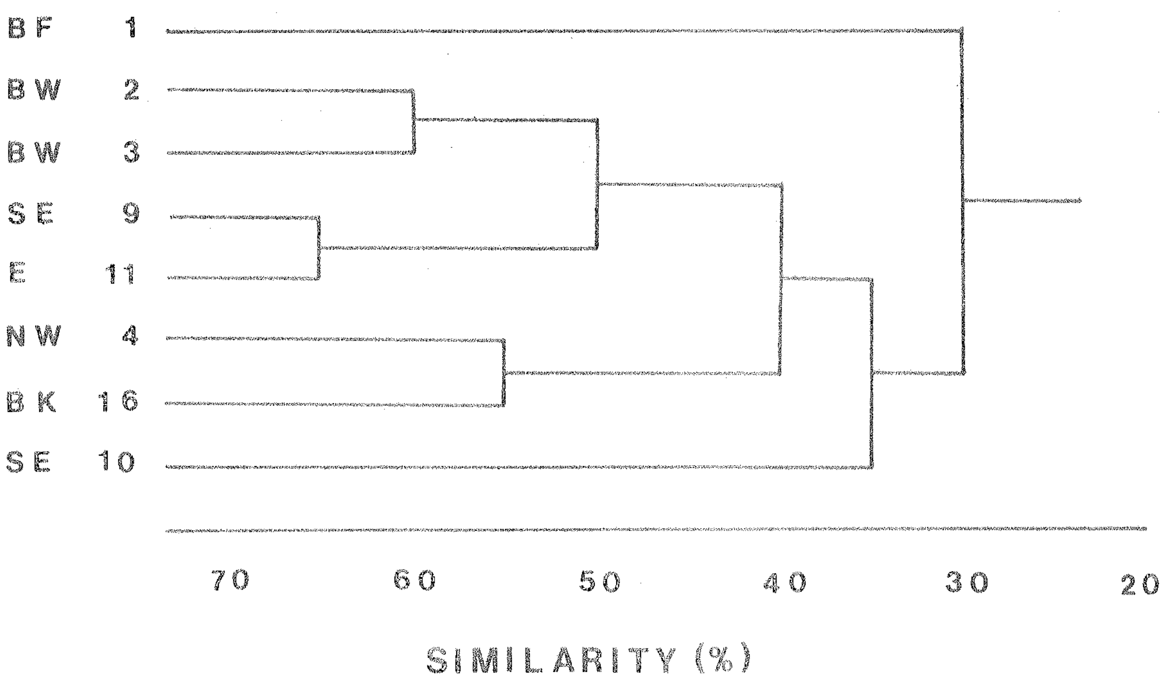
Geographical differences in the compositions of the faunas were also evident in bay estuarine systems and open lagoons (Fig. 7:1b). 'Eastern basins' (regions 9, 11 - 13) were grouped and their affinities to the Tamar River (region 15) and Flinders Island (region 1) were exhibited. These systems are predominantly euhaline and have well developed stands of seagrasses providing refuges for many marine fishes. Northern basins, unlike the Tamar Estuary, have high runoffs and poorly developed seagrasses. This change in composition is dramatically shown in the similarity matrix (Appendix 7:2). The assemblage of fishes inhabiting these habitats on the extreme North-East coast (region 13) is much more similar to those of adjacent eastern regions (similarity to region 11: 62.5, 40 species; region 12: 64.6, 40 species) than to that of the adjacent northern region, (similarity to region 14: 23.3, 15 species). The 'lagoons and bay estuaries of western and southern Tasmania' (regions 5 - 8) were aggregated and 'King Island' (region 16), although once again not ordered into any group, was most similar to the 'West Coast systems' (regions 5, 6).

The fauna of tidal rivers and creeks also exhibited regional differences in composition (Fig. 7:1c). The 5 Bass Strait regions appeared to be distinct from those of the West Coast (regions 4, 5). A few species, which included the wide-ranging *Pseudogobius olorum*, appeared to be absent from these habitats along the West Coast and this was reflected in the similarity matrix (Appendix 7:2). Systems along the western North Coast (regions 2,3) had the greatest similarity and were similar to this habitat type in the

Fig. 7:2. Dendrograms showing levels of similarity of fish assemblages between coastal regions (1 - 16) in the following habitat types: (a) sheltered beaches; (b) exposed beaches. Coastal regions follow those outlined in Section 4:3:4. (1, BF) Furneaux Group. (2, BW) North Coast. (3, BW) Western North Coast. (4, NW) Northern West Coast. (5, W) West Coast. (6, SW) South-West Coast. (7, SC) D'Entrecasteaux Channel. (8, SD) Derwent Estuary. (9, SE) South-East bays. (10, SE) Peninsula. (11, E) East Coast. (12, E) Northern East Coast. (13, NE) North-East Coast. (14, BE) Eastern North Coast. (15, BT) Tamar River. (16, BK) King Island.


BF 1
BW 3
SE 9
SE 10
SC 7
SW 6
E 11
BK 16
70
60
50
40
30
20
SIMILARITY (%)

a


BF 1
BW 2
BW 3
SE 9
E 11
NW 4
BK 16
SE 10
70
60
50
40
30
20
SIMILARITY (%)

b

D'Entrecasteaux Channel (region 7). The island regions of Bass Strait (regions 1, 16) were also aggregated.

Of sheltered beach habitats, those found in the South East (regions 9, 10) were most similar (Fig. 7:2a). The large bays of D'Entrecasteaux Channel (region 7) and the far western North Coast (region 3) were also clustered together in a group. These parts are among the largest sheltered areas around Tasmania in which marine seagrasses are developed. Extensive seagrass stands also occur about the Furneaux Group (region 1) but the presence of at least 4 species found only from that region probably caused it to have a lower highest similarity (i.e. 42.5) than the highest similarity values of regions 3, 7, 9 or 10 (i.e. 49.1 - 56.8) (see Appendix 7:2). These additional species, which are more abundant in warm temperate bays of eastern mainland Australia, have established extra-limital populations in the North-East (see Section 7:3:2). The sheltered beach fauna of eastern Tasmania (region 11), while clustered with that of southwestern Tasmania (region 6), was most similar to the South-East Bays (region 9).

Regional differences were also detectable in the faunas of exposed beaches (Fig. 7:2b). 'Flinders Island' (region 1) experienced comparatively low similarities with all other regions (Appendix 7:2) and appeared to have a distinct fauna. As mentioned earlier (see Section 4:4:4), some sampling areas on the western coast of Flinders Island were subjectively categorised as semi-exposed but bordered on being sheltered habitats. They have extensive seagrass stands and a more diverse fauna (i.e. 33 species compared with 7 - 16 for the other regions). 'Western North Coast' (regions 2,3) and 'northern West Coast' (region 4) - 'King Island' (region 16) were each paired separately. Although 'eastern' (region 11) and 'South-East Bays' (region 9) had the highest similarity value (Appendix 7:3:1), some Peninsula samples (region 10) also had a few species that occur more typically in seagrass habitats.

These data suggest that distinct geographically related trends are present in the composition of shore zone fishes in Tasmania. Although all habitats could not be classified uniformly using identical regional divisions, the faunas of Bass Strait, eastern- southeastern Tasmanian and western Tasmanian components were generally isolated.

In using these analyses, it is important to assess their usefulness and meaningfulness which, in the absence of statistical confidence levels, is clearly difficult. Confidence level tests are not provided with cluster analyses and cannot be performed reliably on this type of data. Nevertheless, based on the consistency with which adjacent regions were aggregated, these results are likely to be meaningful. Furthermore, similar results were obtained using a different clustering technique, a furthest neighbour cluster analysis. Thus it is reasonable to assume that distributional trends do exist within the data but these must now be assessed on a higher zoogeographic scale.

A close examination of similarity values for each analysis (Appendix 7:2) indicated that the range of similarities for each region was generally low (i.e. mostly less than 30%). Hence, regional difference in the faunas of all habitat types are subtle rather than extreme. In comparison, the faunas breaching two different zoogeographic provinces could be expected to have similarity ranges of 50 - 100%.

The fish assemblages of the various habitats of the Tasmanian shore zone can best be viewed as consisting of assemblages of species having compositions that are partly regionally determined. Intra-regional differences in composition appear to be related mainly to local environmental characteristics rather than to latitudinal or longitudinal gradients of zonation. The manner in which these faunas, in particular estuarine faunas, are related to those of other provinces is discussed later (see Section 7:4).

7:3:2 Regional Distributions of Species

The distributions of Tasmanian coastal fishes are poorly known, although Frankenburg (1974), Fulton (1979) and McDowall (1980a) have summarised knowledge of the ranges of some freshwater-estuarine fishes collected in this study. Only species resident to sedimentary habitats were treated in the distributional summary provided below.

Freshwater and Estuarine Species

The proportion of endemism is high in Tasmanian freshwater fishes and some species are restricted to certain drainages and lakes around the island (see Section 7:5). The confined ranges of many galaxiids in inland lakes is well documented (Frankenburg, 1974; McDowall, 1980b) and some coastal freshwater species are equally restricted in their distributions. Typical examples are the smelt, *Retropinna tasmanica,* the grayling, *Prototroctes maraena,* the Tasmanian whitebait, *Lovettia sealii,* the pigmy perch, *Nannoperca australis,* and the flathead gudgeon, *Philypnodon grandiceps.*

Hoese, Larson and Llewellyn (1980) stated that *Philypnodon grandiceps* is rare in Tasmania while Fulton (1979) omitted it from a list of native freshwater species. Specimens were collected in several samples but only from the Mersey River (Appendix 7:1:11).

Retropinna tasmanica has been recorded from the coastal drainages of the North and South-East (Frankenburg, 1974; McDowall, 1980c) but little information is documented on its distribution or habits (Fulton, 1979). This range was extended in the present study to include King Island and some bay estuaries and tidal rivers of the West Coast, however, specimens were not collected from the lagoons of the East, North-East or Flinders Island. This species exhibited a preference for meso-polyhaline waters and should be regarded as an estuarine species. The predominantly euhaline conditions characterising lagoons on the East Coast and Flinders Island may explain the apparent absence of the smelt from these areas.

Frankenburg (1974) and McDowall (1976) have provided distributional maps of *Prototroctes maraena* in Tasmanian waters. The species probably had a statewide distribution in coastal streams (Fulton, 1979) but was since thought to be threatened throughout its range (Lake, 1971; McDowall, 1980d). Individuals were collected recently from western rivers and King Island (Appendix 7:1:2) in previously unsampled areas. It is likely that current populations are larger in some areas than first thought (Bell *et al.*, 1980).

The endemic whitebait, *Lovettia sealii,* has been recorded by Blackburn (1950) in the area extending from the Duck River to the Great Forester River on the North-West, and from the Esperance River to Blackmans Bay in the South (Fulton, 1979). Lynch (1970) recorded ova deposits from the Arthur River and Frankenburg (1974) later reported unconfirmed sitings of individuals from some other western rivers. Reports of the species occurring in western rivers were confirmed with large schools being recorded from the entrances of the Arthur River and Macquarie Harbour (Appendix 7:1:2). The most southerly range was extended to include the Derwent River Estuary and Cockle Creek.

Nannoperca australis has been recorded from northern Tasmanian rivers and from basins on King and Flinders Islands (Scott, 1971; Frankenburg, 1974; Llewellyn, 1980). This species, although abundant in freshwater lakes on King Island, was only collected in mesohaline water from a single northern estuary during a flood (Appendix 7:1:10). Fulton (1979) stated that the species is common throughout much of its range in freshwater.

Distributions of other species regarded as freshwater by Fulton (1979) require some discussion. Two lampreys, *Mordacia mordax* and *Geotria australis,* are widespread in Tasmania (Strahan, 1980a, 80b). As both species spend most of their lives either in the freshwater zones of rivers or in the sea

(Fulton, 1979), only a few individuals were caught when migrating through estuaries.

Two eels are found in the coastal drainages of Tasmania. *Anguilla australis* is mostly widespread throughout rivers in Tasmania (Fulton, 1979) but in New Zealand, populations are concentrated in tidal waters and coastal lakes (Cairns, 1941). McDowall, Hopkins and Flain (1975) maintained that diurnally this species lives amongst vegetation or remains buried in mud when plants are absent. This observation may account for its greater prevalence in the heavily vegetated coastal lagoons of the East and South-East than in the poorly vegetated systems of the West and North (Appendix 7:1:1). A second species, *Anguilla reinhardtii,* occurs in rivers of northeastern and eastern Tasmania (Fulton, 1979). It was rarely collected from saline areas but individuals were observed over rocky bottoms in the deep upper parts of estuaries.

Three galaxiids, *Galaxias brevipinnis, G. maculatus* and *G. truttaceus,* may have marine and freshwater phases to their life cycles. *G. brevipinnis* is widespread in Tasmania (McDowall, 1980b) but it was rarely collected during this study. The adults live mainly in rocky habitats of streams and lakes (Stokell, 1955; McDowall, 1970, 80a; Fulton, 1979) which, in view of sampling methods used herein, probably reduced the likelihood of their capture.

Galaxias maculatus and *G. truttaceus* are also widely distributed in the lower portions of coastal streams (Frankenburg, 1974; Andrews, 1976) but, although recorded from Flinders Island (Fulton, 1979), neither was collected there during this study (Appendix 7:1:2). Adult *G. truttaceus* were only collected from tidal creeks and coastal lakes in fresh or oligo-haline water but juveniles were abundant in spring in the mouths of estuaries and in sheltered marine bays. In comparison, *G. maculatus* is much more common in estuarine systems. The adults probably use estuaries as spawning areas in winter and juveniles are very abundant in oligohaline estuaries in spring.

The brown trout, *Salmo trutta,* is a widespread,introduced species occurring down to sea level (McDowall and Tilzey, 1980). Few individuals were collected in estuaries and the main populations inhabit streams and lakes.

Atherinosoma microstoma is the most widely distributed native estuarine species collected during this study (Appendix 7:1:7). It occurred less frequently in the western, northern and King Island estuaries than in eastern systems. Smaller quantities of *Zostera* and other seagrasses, which are preferred habitats (Ivantsoff, 1980), occur in the tidal rivers and creeks of the North and West than in the euhaline lagoons of the East may be a contributing factor.

The hairy pipefish, *Urocampus carinirostris,* was collected only from estuaries along the eastern coast (Appendix 7:1:4). The species has been recorded previously from the Tamar River (Scott, 1971) and the Carlton River (Scott, 1965). Its distribution in Tasmania may also be associated with the occurrence of *Zostera* and *Ruppia*.

The black bream, *Acanthopagrus butcheri,* was collected from the eastern and southeastern estuaries (Appendix 7:1:10). While this species is known to occur in a few other systems nearby, it is clearly less common outside these regions. Populations are reputed to exist in the Piper, Rubicon, Franklin, Mersey and Arthur Rivers and other unofficial records from the Little Piper and St. Pats Rivers are known to the author.

The congolli, *Pseudaphritis urvillii,* is widespread around Tasmania (Andrews, 1980). Frankenburg (1974) and Hortle (1978) provided distribution maps of the species on which it is recorded several miles inland.

P. urvillii appeared to be most common in the estuaries of the East and South-East (Appendix 7:1:11).

The bridled goby, *Amoya bifrenatus*, was collected only from estuarine systems although in mainland Australian waters it regularly occurs in marine environments (Hoese and Larson, 1980). It has previously been recorded from the Tamar River (Whitley, 1954; Scott, 1976) and Georges Bay (Olsen, 1958; Scott, 1963). As the species is a burrower (Hoese and Larson, 1980) it may be represented in each area by a resident population. Localised populations were found in many northeastern lagoons, in Duck River and near Cygnet (Appendix 7:1:12). T. Walker (personal communication) collected several specimens from North West Bay near the entrance to Nierinna Creek.

The Tamar goby, *Favonigobius tamarensis*, is widely distributed in estuaries around Tasmania and on the Bass Strait Island (Appendix 7:1:12). It occurred most frequently in the South and East.

The blue-spot goby, *Pseudogobius olorum*, was collected from estuaries of the North, East and South-East Coasts and Flinders Island (Appendix 7:1:12). Hoese and Larson (1980) claim that the species is common in muddy and weedy estuaries and in coastal lakes. Along with *Favonigobius tamarensis*, *Pseudaphritis urvillii*, *Urocampus carinirostris* and *Atherinosoma microstoma*, it is most common in estuaries of the East and South-East and this may possibly be linked with greater preferred habitat availability.

Two species of *Tasmanogobius* are found in estuarine systems. *T. lordi* is known only from coastal Tasmania (Hoese and Larson, 1980) and, although appearing to be most common in northern systems, it was not collected from the Bass StraitIslands (Appendix 7:1:12). *T.* sp. 3 was recorded from both Flinders and King Islands but occurred more frequently in the East and South-East than elsewhere.

Marine Species

The coastal distributions of marine fish species are generally less disjunct than their estuarine and freshwater counterparts. Nevertheless, the availability of a suitable habitat type does restrict the ranges of some marine species and, considering the paucity of information on the distributions of almost all the species collected, important patterns need to be presented.

The ubiquitous shore zone species, *Aldrichetta forsteri*, *Atherinosoma presbyteroides*, *Arripis trutta*, *Nesogobius* sp. 2, *Ammotretis rostratus* and *Rhombosolea tapirina*, are widespread around Tasmania and the Bass Strait Islands (Appendix 7:1), the only exception being the absence of *R. tapirina* from samples taken around King Island (Appendix 7:1:3).

Other species that are widely distributed include *Ammotretis liturata*, *Stigmatopora argus*, *S. nigra*, *Gymnapistes marmoratus*, *Platycephalus bassensis*, *Neoodax balteatus*, *Cristiceps australis*, *Heteroclinus perspicillatus*, *Acanthaluteres spilomelanurus* and *Torquigener glaber*.

Crapatalus arenarius is common and widespread on exposed beaches around Tasmania. An undescribed congener, *Crapatalus* sp., occurs on beaches of light to moderate exposure and was absent from the highly exposed beaches of the West Coast and King Island.

Some species, *Platycephalus castelnaui* and *Neoodax radiatus*, were collected only at sampling sites from Bass Strait, whereas *Spratelloides robustus* and *Contusus* sp., although occurring elsewhere, were much more common in this area (Appendix 7:1).

Disjunct distributions were evident for *Syngnathus phillipi*, *Atherinason esox*, *A.* sp., *Platycephalus laevigatus*, *Neoodax semifasciatus* and *Tasmanogobius* sp. 1 (Appendix 7:1). They occurred in the heavily vegetated sheltered habitats of Bass Strait and in similar habitats of southeastern Tasmania.

Hippocampus abdominalis was collected only from parts of the South-East (Appendix 7:1:5). Lovett (1969) provided distributional notes on this species in the Derwent River area but did not consider other areas of the state.

Six species of the marine goby genus, *Nesogobius*, were collected in this study and all are diagnostic of the cool temperate Australian region. As mentioned earlier, *N.* sp. 2 is widespread around Tasmania and was also collected from King and Flinders Islands (Appendix 7:1:13). Interestingly, none of the other species was collected near the Bass Strait Islands, although *N. hinsbyi*, *N. pulchellus* and *N.* sp. 7 were sampled off Bruny Island (Appendix 7:1:13) and *N. pulchellus* and *N.* sp. 7 were also collected off sheltered beaches on Maria Island. *N. hinsbyi* and *N.* sp. 5 were collected in several regions but, like the other *Nesogobius* species, they were not generally common outside the South-East. *N.* sp. 3, the only exception, was caught in the entrance of the Tamar River.

Several species were seldom sampled or were only represented as a single individual. These fishes consisted mostly of transient reef species and juveniles of species from adjacent environments. Some subtropical species were represented by small isolated populations or as solitary juveniles in northern regions.

Isolated populations of *Leptonotus costatus* and *Amoya frenatus* were found in restricted localities in the Furneaux Group. Each was abundant within its range but neither had been previously recorded from Tasmania. *A. frenatus* has been recorded in moderate numbers in several estuarine systems from New South Wales (Thomson, 1959; Bell, 1980) and along with *L. costatus* certainly favoured more northerly regions. The same situation possibly applied to *Cristiceps argyropleura*, *Syngnathus poecilolaemus*, *S. curtirostris*, *Hypselognathus rostratus*, *Leptoichthys fistularius*, *Siphonognathus argyrophanes* and *Siphamia cephalotes* (Appendix 7:1). These species, either new records or rarely recorded from Tasmania, were also found only in Bass Strait. Juvenile *Pomatomus saltator* and *Upeneus tragula*, the adults of which are normally found in warm temperate or tropical waters (Munro, 1967; Grant, 1978) and *Dicotylichthys myersi* (=*punctulatus*), which was thought to be confined to southern Queensland and New South Wales (Leis, 1982), were collected from an open lagoon in the Furneaux Group.

Juveniles of reef fishes or offshore demersal and pelagic species were sometimes collected. For example, *Cheilodonichthys kumu, Upeneichthys lineatus, Kathetostoma laeve* and *Sillago bassensis* are commonly taken on the inner continental shelf by trawlers (Last and Harris, 1981) while *Trachurus declivis* is a potentially important commercial pelagic species (Maxwell, 1979). The adults of *Genypterus* sp., *Enoplosus armatus, Penicipelta vittiger* and *Eubalichthys gunnii* normally inhabit rocky reef habitats.

Common rocky reef species occasionally entered the sampling areas as adults and some were probably caught incidentally. Thus their distributions, based on occurrences in sedimentary habitats, are incomplete. These species included *Apogon conspersus, Bovichthys variegatus, Pictiblennius tasmanianus, Pseudolabrus tetricus, Diodon nicthemerus, Aracana aurita, Ophiclinus gracilis, Alabes parvulus* and *A. dorsalis*.

7:4 RELATIONSHIPS OF THE TASMANIAN ESTUARINE FISH FAUNA

The fish fauna of Tasmanian estuaries consists of 216 native species and 2 exotic species, the brown trout (*Salmo trutta*) and rainbow trout (*Salmo gairdnerii*)(Appendix 7:3) Of these, almost three-quarters (154 species) are coastal marine species of which 124 species are endemic to Australian waters (Table 7:1). The families Atherinidae (4 species), Syngnathidae (11 species), Labridae (5 species), Tripterygiidae (4 species) Odacidae (6 species), Clinidae (9 species), Gobiidae (9 species), Pleuronectidae (4 species) and Monacanthidae (7 species) are dominant groups.

Freshwater and estuarine species, which have been discussed earlier, are represented by Australian endemics of the families Gobiidae (6 species), Retropinnidae (1 species), Atherinidae (1 species), Plotosidae (1 species), Syngnathidae (1 species), Percichthyidae (1 species), Sparidae (1 species), Kuhliidae (1 species), Eleotridae (1 species) and Bovichthyidae (1 species).

Migratory fishes consist of 9 species from the families Galaxiidae (3 species), Anguillidae (2 species), Geotriidae (1 species), Mordaciidae (1 species), Prototroctidae (1 species), and Aplochitonidae (1 species). Some of these species have wide distributions.

Offshore species entering estuaries comprise a rather surprisingly large 18% of the fauna as almost half of these normally live demersally on the continental shelf as adults. Species such as *Pterygotrigla polyommata* (Triglidae), *Galeorhinus australis* (Carcharhinidae), *Cyttus australis* (Zeidae), *Platycephalus richardsoni* (Platycephalidae), *Nemadactylus macropterus* (Cheilodactylidae) and *Seriolella brama* (Centrolophidae) occurred in estuaries only as juveniles or sub-adults. Similarly, juveniles of *Helicolenus papillosus* (Scorpaenidae), *Genypterus blacodes* (Ophidiidae) *Macruronus novaezelandiae* (Merlucciidae) and *Seriolella punctata* (Centrolophidae), which are most widely distributed on the continental slope as adults (Last and Harris, 1981) were also recorded from estuaries.

Pelagic (7 species) and oceanic (8 species) groups are represented by *Dasyatis guileri* (Dasyatidae), *Sphyrna zygaena* (Sphyrnidae), *Cetorhinus maximus* (Cetorhinidae), *Thyrsites atun* (Gempylidae), *Lepidopus caudatus* (Trichiuridae), *Mola ramsayi* (Molidae), *Caranx georgianus* (Carangidae), *Trachurus declivis* (Carangidae), and the scombrids *Auxis thazard, Gasterochisma melampus, Katsuwonus pelamis, Scomber australasicus* and *Thunnus maccoyii.*

Table 7:1. General summary of distributions and environments of (a) the Tasmanian estuarine fish fauna and (b) the Tasmanian fish fauna. Data is based on Last (in preparation).

	Estuarine fauna (numbers of species)				Tasmanian fauna (numbers of species)			
	Australia	Australia/ New Zealand	Widely distributed	Total	Australia	Australia/ New Zealand	Widely distributed	Total
Freshwater	4	-	-	4	17	-	-	17
Estuarine	12	-	-	12	12	-	-	12
Migratory	5	2	2	9	5	2	2	9
Coastal marine	124	23	7	154	193	28	9	230
Offshore demersal (Continental shelf)	9	5	4	18	63	39	6	108
Offshore demersal (Continental shelf)	-	2	2	4	13	14	44	71
Pelagic	1	2	4	7	5	5	6	16
Oceanic	1	1	6	8	4	8	70	82
Total	156	35	25	216	312	96	137	545

Most of these species consist of wide-ranging forms and, with the exception of *Caranx, Trachurus* and *Thyrsites*, were infrequent visitors to these habitats.

Ranges of animals in marine environments are mostly less confined than those on land (Peilou, 1979). Many mobile species, in particular, are capable of occurring extra-limitally as individuals or occasionally in non-breeding populations. Thus, breeding ranges, rather than general distributions, are probably more useful in assessing the zoogeographic affinities of a species. Unfortunately, few studies have provided information on the breeding ranges of Australian temperate fishes. In this study, breeding ranges were determined on the regional co-occurrences of adults and juveniles which were estimated from distributional records, unpublished data, internal fisheries reports and personal communications with other regional authorities (e.g. R. Kuiter, B. Hutchins, G. Edgar). The author has made supportive observations while on diving trips to most areas of Southern Australia. Although not objective, this method was considered to be a reasonable approximation in most cases and the best approach available under the circumstance.

Compositionally, the Tasmanian estuarine fish fauna consists mostly of Australian endemics (approximately 70%) with some Australasian species (approximately 17%) and a residue of more widely distributed species (Table 7:1).

Some Australian endemics (about 70 species) have restricted distributions or breeding ranges which coincide with the zoogeographic provinces outlined by Whitley (1932) and others. Provincial elements were recognised from the Maugean (cold temperate), Flindersian (western warm temperate), Peronian (eastern warm temperate) and the Solanderian (eastern tropical) Provinces. Other species, although often having centres of distribution in one province, occurred widely throughout southern Australia.

Table 7:2. Zoogeographical structure of the Tasmanian estuarine fish fauna based on Australian endemics.

Provincial	Number of Species
Maugean	39
Flindersian	22
Peronian	8
Solanderian	1
Southern Australia	
widespread	44
mainly Maugean	22
mainly Flindersian	16
mainly Peronian	4

The largest provincial element consisted of 39 cold temperate species (Table 7:2) and the Flindersian component (22 species) appeared to be larger than the Peronian component (8 species). The predominance in the fauna of western warm temperate species over eastern warm temperates was also exemplified amongst the widely-distributed southern Australian species which had a centre of distribution in one province. Sixteen of these had Flindersian affinities but only 4 were predominantly Peronian. Edgar (1981) also noted that Tasmanian reef fishes possessed a close Flindersian affinity which was most evident in Bass Strait, whereas a small Peronian element was found to be best represented off the East Coast. The situation in estuaries is similar. In summer, northeastern systems may receive an insurgence of juvenile Peronian, Solanderian and an occasional Indo-Pacific species from the southward flowing East Australian Current (see Section 7:3:2). These juveniles appeared to be distributed more southward down the East Coast than westward through Bass Strait.

Forty-four fishes are distributed widely around southern Australia and have no strong affinity with any province. Most of these are coastal marine species but one oceanic species, *Dasyatis guileri* (Dasyatidae), fitted this category. A further 36 species, including offshore species of the families Carcharhinidae,Merlucciidae, Zeidae, Scorpaenidae, Triglidae, Carangidae, Cheilodactylidae, Latridae, Scombridae and Centrolophidae, also occur around the shores of New Zealand.

All estuarine and freshwater species are restricted to Australia but 4 migratory species occur outside this region. *Anguilla australis* (Anguill-idae) and *Galaxias brevipinnis* (Galaxiidae) are found in New Zealand. *Geotria australis* (Geotriidae) and another galaxiid, *Galaxias maculatus*, also occur in New Zealand and South America (McDowall, 1968).

Twenty-three widely distributed and totally marine species occur in Tasmanian estuaries and about two-thirds of these are offshore species.

Coastal species are represented by members of families Hexanchidae, Carcharhinidae, Dasyatidae, Pomatomidae, Sciaenidae, Mugilidae and Mullidae but most are rarely found in estuarine habitats.

The estuarine fish faunas of southern Australia, represented by the Maugean (Tasmania, Victoria), the Flindersian (southern Western Australia) and the Peronian Provinces (New South Wales), were compared by cluster analysis with those of other temperate regions, namely eastern and western U.S.A., New Zealand, South Africa, Japan and the United Kingdom. Faunal lists used as data were based on comprehensive studies (or a combination of studies) in each area, but lists for Victoria and New Zealand were possibly less complete. To the author's knowledge comparable lists are currently unavailable for cool temperate areas of South America, although a study on the fishes of Rio Deseado Estuary, Argentina is currently in progress (A. Gosztonyi, personal communication).

The cluster analysis grouped faunas of the Southern and Northern Hemispheres (Fig. 7:3).

A close association between the Tasmanian and Flindersian faunas was evident from their similarity values. In addition, the estuarine fauna of New South Wales exhibited a closer similarity to these faunal groups than did the South African fauna. Less complete Victorian and New Zealand lists were aggregated with other Southern Hemisphere groups but exhibited weaker associations. Cluster analyses generally rely on the use of complete data so the low similarities obtained for these faunas are probably somewhat artificial. A repeat analysis, with the Victorian and New Zealand faunas removed, resulted in identical clustering of the remaining faunal groups.

The Northern Hemisphere groups were clustered according to their regionality. Estuarine fishes from the North Atlantic region (United Kingdom and eastern United States groups) were more similar to each other

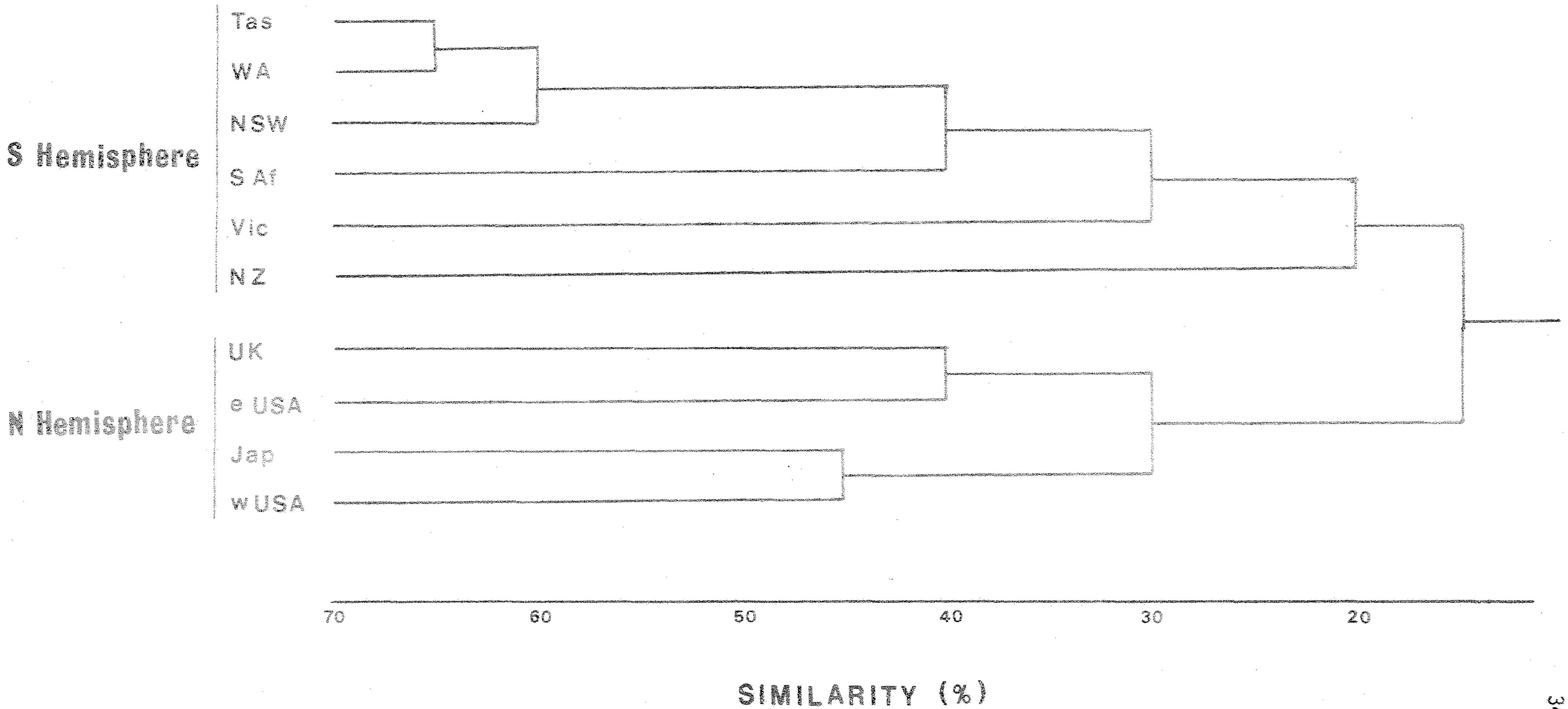


Fig. 7:3. Dendogram showing levels of similarity of some temperate estuarine faunas at the family level. (Tas) Tasmania. (WA) Western Australia. (NSW) New South Wales. (SAf) South AFrica. (Vic) Victoria. (NZ) New Zealand. (UK) United Kingdom. (eUSA) eastern United States. (Jap) northern Japan. (wUSA) western United States.

than to the North Pacific groups (Japan and western United States).

Although some obvious differences existed in the regional occurrences of teleost families, elasmobranch families were mostly widespread over all regions. Representatives of the latter are mainly transient in estuaries and thus are not useful in depicting geographic differences in composition. Similarly, families unique to only one region contribute more to group dissimilarity than to similarity. Separate analyses, with data on elasmobranchs and endemic families removed, resulted in a classification of faunal groups arranged identically to Figure 7:3.

In comparing the inter-regional characteristics of the faunas of specified habitats, it is important to consider the resemblances and contrasts of each community or faunal type. Pielou (1979) recognised two similar types of regional communities. The first kind relates to a community whose component species share matching congenerics with a second community. Such communities, although geographically separate, have converged or developed in parallel. In the second situation, both species and communities have developed convergently; the general community structures are similar but their taxonomic compositions are different. Consequently, in each region, superficially similar but often totally unrelated forms can fulfil the same ecological roles. A further category consisting of unmatched pairs of communities which differ taxonomically and also in community structure may sometimes exist. In this situation, the ecological roles of species are either different or are enacted by totally different forms. The first category outlined by Pielou (1979) best characterises the situation existing within the zoogeographic provinces of southern Australia.

The concept of community pairs (matching congenerics) is best demonstrated within the warm temperate faunas of Australian estuaries. Eastern and western sibling species of *Urolophus*, *Upeneus*, *Sillago*, *Arripis*, *Acanthopagrus*, *Platycephalus*, *Cheilodactylus*, *Hyporhamphus*, *Syngnathus* and *Scorpaena* are important components in each province. Some of these, plus additional cold temperate congenerics, also occur in Tasmanian waters.

Knox (1980) has attributed the formation of a land barrier between Tasmania and mainland Australia and a period of glaciation in the Pleistocene era as causes for the derivation of provincial elements (or community pairs) in temperate Australia. Northward movement of the subtropical convergence may have resulted in a migration of southern species up both the East and West coasts of Australia providing an ideal situation for allopatric speciation. A southward regression of the convergence and the reformation of Bass Strait would ensure an overlapping distribution of many southeastern and southwestern components.

In addition to being similar in composition at the family level, estuarine faunas of southern Western Australia also share considerable resemblance in species composition to those of Tasmania. Of the 18 most abundant species taken in the Blackwood River Estuary (Lenanton, 1977), 11 occur in Tasmanian estuaries. Only one of the remaining genera, *Helotes* (f. Theraponidae), is not represented in Tasmania. Also, at least 19 of a further 31 less common western estuarine species have been recorded from local estuaries.

Tasmanian and some Victorian estuaries appear to have similar faunas. Nineteen of the 20 most abundant species in the Gippsland Lakes, based on field trip summaries and an interim report (1979) on the fishes by B. Rigby, occur in Tasmanian estuaries. The remaining species, *Arripis georgianus*, is represented around Tasmania by congenerics. One of these, *A. trutta*, is very abundant in coastal areas and estuaries of Tasmania and its absence from Rigby's list seems surprising. Scott, (1976) has misidentified juvenile *A. trutta* for *A. georgianus*. At this stage of development these species are similar and it is possible that confusion may have arisen in the Victorian study. Rigby (1979) indicated that 5 species, *Engraulis australis*, *Aldrichetta* *forsteri, Atherinosoma microstoma, Acanthopagrus butcheri* and *Pseudaphritis urvillii*, comprised the bulk of the seine catches. These species are also major components of many Tasmanian estuaries, particularly the polyhaline or euhaline systems along the eastern coast.

The resemblance between the major species in Botany Bay and those occurring in Tasmanian estuaries is comparatively smaller. Of 21 species occurring in the former (Bell, 1980), only 6 have been recorded from the latter. Two families, Ambassidae and Theraponidae, and 7 genera, *Harengula* (Clupeidae), *Pranesus* and *Pseudomugil* (Atherinidae), *Centropogon* (Scorpaenidae), *Liza* (Mugilidae), *Bathygobius* (Gobiidae) and *Pseudorhombus* (Bothidae), are not represented in Tasmanian estuaries.

In accordance with the situation in estuaries, the Flindersian component of the entire Tasmanian coastal marine fauna is about 2.5 times larger than that of the Peronian element (Last, in preparation). The eastern provincial element, however, appears to have a closer affinity with the New Zealand fauna than with the southwestern Australian component. Of the 36 Australasian endemics (species whose distributions are confined to New Zealand and Australia) found in Tasmanian estuaries, all occur off Victoria, about 86% off New South Wales, about 92% off South Australia and only about 56% off Western Australia. For example, species including *Girella tricuspidata* (Kyphosidae), *Atypichthys strigatus* (Scorpidae), *Parma microlepis* (Pomacentridae), *Cheilodactylus spectabilis* (Cheilodactylidae) and *Pseudolabrus fucicola* (Labridae), which are confined largely to eastern Australia and New Zealand, when added to Peronian endemics tend to almost counterbalance the size of western elements in the fauna. Other Tasmanian coastal marine fish, *Chromis hypsilepis* (Günther) (Pomacentridae), *Chironemus marmoratus* Günther (Chironemidae) and *Suezichthys* sp. and *Bodianus* sp. (Labridae), which are not found in estuaries, also exhibit a Peronian-New Zealand distribution.

The northward movements of the subtropical convergence, which is thought to have extended almost to the northern tip of the North Island, is considered to be responsible for the demise of many New Zealand coastal animals (Knox, 1980). Although little information is available on the phylogenies of most of the fish genera concerned, Russell (1980) has suggested that the ancestral Australian labrid stock was not eliminated but adapted in response to lower temperatures in the late Eocene - early Oligocene. *Pseudolabrus fucicola*, which is confined in distribution to southeastern Australia and New Zealand, is possibly derived from a widespread trans-Tasman ancestor. This ancestoral wrasse, initially derived from the original labrid stock, is also responsible for two other siblings in New Zealand, suggesting that adaptation, rather than recolonisation, occurred within the region. It is likely that similar patterns of derivation may have occurred within groups that have distributions of congenerics matching these wrasses (i.e. Cheilodactylidae, Latridae, Pleuronectidae, Tetraodontidae).

The knowledge of fish in New Zealand estuaries is meagre but the fauna appears to be low in diversity (McDowall, 1976). Studies by Webb (1972, 73b) and Kilner and Akroyd (1978) listed a total of only 42 species. Nevertheless, many components of the New Zealand and cold temperate Australian estuarine faunas are similar; members of the families Retropinnidae, Prototroctidae and Arripidae are endemic to Australasia. New Zealand species such as *Aldrichetta forsteri*, *Girella tricuspidata*, *Anguilla australis*, *Galaxias maculatus*, *Pseudaphycis bachus* and *Caranx georgianus* are also common in many Tasmanian estuaries. In addition, there are examples of parallel evolution in *Rhombosolea* and *Latridopsis* and in the families Uranoscopidae, Tripterygiidae and Eleotridae. However, some important groups occurring in southern Australian estuaries are apparently absent from New

Zealand estuaries; these include atherinids, scorpaenids, platycephalids, odacids, clinids, gobiids and monacanthids.

McDowall (1976) stated that few freshwater species are resident in estuaries and only a *Tripterygion* species may be regarded as truly estuarine. Similarly, few marine species appear to have resident populations in these estuaries. Coastal marine habitats of New Zealand contain at least as many species (Moreland, 1959) as those of Tasmania but the small size of most New Zealand estuaries, combined with their extensive tidal flushing, may make them of low importance to marine fish (McDowall, 1976). In addition, seagrasses, which are productive habitats of Australian estuaries, are absent from New Zealand estuaries. Thus, groups such as the families Syngnathidae, Odacidae, Clinidae and Monacanthidae, whose members exhibit an affinity for these habitats (see Section 4:5:2), are poorly represented in the New Zealand fish fauna.

Wallace (1975a) listed 232 species from Natal estuaries. This fauna contains about 70% of tropical species and typifies a subtropical province (Day, Blaber and Wallace, 1981). The cold temperate province of southern Africa is represented along the Atlantic coast but, because species lists from estuaries in this area appear to be less complete, data from Natal estuaries were used in the regional analysis (see Fig. 7:3). Groups that are primarily tropical in distribution, such as the families Elopidae, Muraenidae, Fistulariidae, Theraponidae, Lutjanidae, Lethrinidae, Monodactylidae, Chaetodontidae, Cirrhitidae, and Polynemidae, were found in these estuaries and, although several also occur in warm temperate estuaries of Western Australia and in Botany Bay, none is represented in Tasmanian estuaries. Two Indo-Pacific families, the Sillaginidae and Platycephalidae, are also represented in cold temperate Australian estuaries. The centre of origin for these groups may have been the Indian Ocean as they are not found in either New Zealand or South America. At least one group, the coracinids, are endemic to this region.

The estuarine fish faunas of the Northern Hemisphere appear to be distinct from those of the Southern Hemisphere. Many groups such as the families Acipenseridae, Esocidae, Osmeridae and Gasterosteidae are endemic to the Northern Hemisphere. The families Ammodytidae, Cottidae, Zoarcidae, Salmonidae, Cyprinidae and Cyprinodontidae do not have native species in any of the Southern Hemisphere estuaries listed, although a few representatives of the last 3 families have been widely introduced to austral regions.

Several stichaeids and pholidids are found in estuaries of this region. These groups also occur in the North Atlantic (Nelson, 1976) but were not listed in the studies referred to herein. Two families, the Hexagrammidae and Embiotocidae, in estuaries are confined to the North Pacific coasts.

Members of the freshwater fish family Percidae are widely distributed in freshwater basins and streams throughout North America and parts of Eurasia. In coastal areas, however, they are native only to systems draining into the North Atlantic and Arctic Oceans (Nelson, 1976). Other groups have more confined distributions within the North Atlantic. For example, in temperate areas members of the families Ictaluridae and Centrarchidae are restricted to rivers or streams draining into the western North Atlantic.

A notable feature of the fauna lists is the presence of a suite of families that are widespread in most temperate estuaries. These include the families Carcharhinidae, Dasyatidae, Clupeidae, Engraulidae, Anguillidae, Exocoetidae, Atherinidae, Syngnathidae, Scorpaenidae, Triglidae, Pomatomidae, Carangidae, Sparidae, Sciaenidae, Mugilidae, Sphyraenidae, Labridae and Blenniidae. Many of these groups are also dominant throughout a wide range of seagrass habitats in many geographical localities (Pollard, 1982).

A number of groups were found only in Australian estuaries. The families Brachionichthyidae, Pataecidae and Enoplosidae are endemic to

Australian waters. Others, including members of the families Odacidae, Percicthyidae, Aplodactylidae, Gonorynchidae, Moridae, Pempheridae, Zeidae and Cheilodactylidae, which occur in coastal habitats outside Australia, were not recorded from estuaries in any of the overseas studies discussed above.

7:5 ENDEMISM IN THE TASMANIAN FISH FAUNA

The history of biotic distributions can be explained by dispersal and vicariance mechanisms (Knox, 1980). Ancestral biotas, after being modified by speciation, isolation, immigration and extinction, have produced the present faunas. A major factor in the evolution of provinical elements in the shore zone of Southern Australia has been the successive periods of glaciation, the subsequent formation of land barriers in Bass Strait and latitudinal shifts in the water temperature boundaries (Dartnall, 1974). Although these events have been responsible for the derivation of endemic elements amongst the flora and the invertebrate fauna (Knox, 1980), regional endemism in the Tasmanian marine fish fauna has not been treated comprehensively in a recent account (Briggs, 1974).

The following list of Tasmanian endemics (Table 7:3) is derived from an annotated checklist of Tasmanian fishes (Last, in preparation). Thirty-eight nominal and undescribed species are endemic to this region, however 7 of these are likely to be conspecific with species also occurring along the coast of mainland Australia. In addition, the validity of the *Muraenichthys* species is questionable (J. McCosker, personal communication).

Of the 38 species that occur locally and are presently undescribed, only 6 have not been recorded from outside Tasmania. These consist mainly of handfishes, *Brachionichthys* spp., which appear to have restricted

Table 7:3 Tasmanian endemic fishes. Those species marked with an asterisk are probably conspecific with Australian mainland forms.

ORECTOLOBIDAE

Parascyllium multimaculatum Scott, 1935
(Tasmanian Spotted Catshark) - Marine

MURAENIDAE

**Gymnothorax leecote* Scott, 1965
(Scott's Moray Eel) - Marine

OPHICHTHIDAE

Muraenichthys lengomena Scott, 1980
(Bar-tailed Worm Eel) - Marine

Muraenichthys lingowenah Scott, 1975
(Scott's Worm Eel) - Marine

RETROPINNIDAE

Retropinna tasmanica McCulloch, 1920
(Tasmanian Smelt) - Estuarine

GALAXIIDAE

Galaxias auratus Johnston, 1883
(Golden Galaxias) - Freshwater

G. cleaveri (Scott, 1934)
(Tasmanian Mudfish) - Freshwater

G. fontanus Fulton, 1978
(Swan Galaxias) - Freshwater

G. johnstoni Scott, 1936
(Clarence Galaxias) - Freshwater

G. parvus Frankenburg, 1968
(Dwarf Galaxias) - Freshwater

G. pedderensis Frankenburg, 1968
(Pedder Galaxias) - Freshwater

G. tanycephalus Fulton 1978
(Saddled Galaxias) - Freshwater

Paragalaxias dissimilis (Regan, 1905)
(Shannon Paragalaxias) - Freshwater

P. eleotroides McDowall and Fulton, 1978
(Great Lake Darter) - Freshwater

P. mesotes McDowall and Fulton, 1978
(Arthur's Paragalaxias) - Freshwater

P. julianus McDowall and Fulton, 1978
(Julian Paragalaxias) - Freshwater

APLOCHITONIDAE

Lovettia sealii (Johnston, 1883)
(Tasmanian Whitebait) - Anadromous

BYTHITIDAE

Dermatopsoides sp. - Marine

Microbrotula sp. - Marine

BRACHIONICHTHYIDAE

Brachionichthys hirsutus (Lacepede, 1804)
(Spotted Handfish) - Marine

BRACHIONICHTHYIDAE (Cont.)

Brachionichthys laevis (Lacepede, 1804)
(Lacepede's Handfish) - Marine

Brachionichthys politus (Richardson, 1849)
(Red Handfish) - Marine

Brachionichthys sp. 1
(Ziebells Handfish) - Marine

Brachionichthys sp. 2
(Australian Handfish) - Marine

Brachionichthys sp. 3
(Storm Bay Handfish) - Marine

SYNGNATHIDAE

Syngnathus mollisoni Scott, 1955
(Mollison's Pipefish) - Marine

PATAECIDAE

**Aetapcus armatus*(Johnston, 1891)
(Johnston's Prowfish) - Marine

KYPHOSIDAE

**Kyphosus diemenesis* Scott,
(Tasmanian Drummer) - Marine

BOVICHTHYIDAE

**Bovichthys angustifrons* Regan, 1913
(Tasmanian Dragonet) - Marine

TRIPTERYGIIDAE

**Helcogramma clarkei* (Morton, 1888)
(Clark Threefin) - Marine

Forsterygion multiradiatum Scott, 1977
(Many-rayed Threefin) - Euryhaline Marine

F. gymnotum Scott, 1977
(Bare-backed Threefin) - Euryhaline Marine

**Tripterygion whitleyi* Scott, 1977
(Whitley's Threefin) - Marine

GOBIIDAE

Favonigobius sp. - Freshwater

Tasmanogobius lordi Scott, 1935
(Lord's Goby) - Estuarine

BOTHIDAE

Arnoglossus andrewsi Kurth, 1954
(Andrew's Flounder) - Marine

**A. armstrongi* Scott, 1975
(Armstrong's Flounder) - Marine

PLEURONECTIDAE

Ammotretis macrolepis McCulloch, 1914
(Large-scaled Flounder) - Marine

Taratretis derwentensis Last, 1978
(Derwent Flounder) - Marine

distributions even within this region. Another form resembling *Brachionichthys* sp. 1 may also be a valid endemic.

A recent survey of coastal reef fishes by Hutchins has uncovered several small cryptic fishes which are unrecorded from Tasmanian waters. Two bythitids, *Dermatopsoides* sp. and *Microbrotula* sp. (Cohen, personal communication) have been collected only in this region and a few gobiesociids remain unidentified (Hutchins, personal communication). A decision as to the validity of *Favonigobius* sp., collected from King Island, awaits the aquisition of additional material.

Of the formerly undescribed species collected in this study (see Section 3:1) only *Taratretis derwentensis* appears to be endemic. *Dasyatis guileri* was collected from the Great Australian Bight (Collins and Baron, 1981), *Atherinason* sp. from Victoria (Ivantsoff, personal communication), *Tasmanogobius* spp. from Kangaroo Island (Glover, 1979; Hoese, personal communication) and *Contusus* sp. (= *brevicaudus)* from southern mainland Australia (Hardy, 1981). The author has recently inspected specimens of a *Crapatalus* sp. from South Australia and Victoria and found them to be conspecific with the Tasmanian form.

Some other species, such as *Mendosoma allporti* Johnston and *Syngnathus tuckeri* Scott, once thought to be endemic, have now been found in other regions. *M. allporti* is regarded as a junior synonym of *M. lineatus* Guichenot from New Zealand (R. White, personal communication), while *S. tuckeri* has been collected from New South Wales (Dawson, 1978).

Alternatively, recent studies have shown that some species once thought to be conspecific with mainland forms may be distinct species. Jackson and Llewellyn (1980) have detected such differences in the populations of *Gadopsus marmoratus*. Electrophoretic studies may also serve to isolate specific differences in the subspecies of *Nannoperca australis*.

About a third of the Tasmanian endemics are found only in freshwater.

This group is dominated by the galaxiids of Tasmanian lakes and rivers and their evolutionary biology and zoogeography have received considerable attention (e.g. Frankenburg, 1974; Fulton, 1979; McDowall, 1981).

Twenty-three indigenous species have been found only in marine habitats of the coastal zone of Tasmania. Major groups, in addition to those mentioned earlier, include the threefin blennies (Tripterygiidae) and flatfishes (Bothidae and Pleuronectidae). Unlike the brachionichthyids, which are found only in Australia, these families are widespread (Nelson, 1976).

Two species, *Retropinna tasmanica* and *Tasmanogobius lordi*, are endemic to Tasmanian estuaries but may enter freshwater. An anadromous species, *Lovettia sealii,* is also confined to this region. This is rather unusual as anadromous fishes in other regions generally have wide distributions.

The Maugean element of the Tasmanian fish fauna includes a number of species, other than those discussed above, that are endemic to cool temperate waters of Australia. Of 36 species, all except *Pseudaphritis urvillii* and *Tasmanogobius* sp. 3 are marine. Briggs (1974) stated that 4 of 7 rajids, 10 of 13 clinids, 1 of 2 bovichthyids and 3 of 5 ostraciontids were probably endemic to this province. However, his interpretations of the faunal characteristics have proved to be largely inaccurate. The Clinidae now contains more than 17 species in this region and only 6 are provincial endemics. Also, only 2 of at least 9 rajids and no ostraciontids are endemic to cool temperate Australia.

The family Bovichthyidae is a member of the predominantly Antarctic and sub-Antarctic Notothenіiformes and represents the only polar element in the Tasmanian fauna. The closely related nototheniids, which are represented by several species in South America and New Zealand, do not occur in this region. McDowall (1980e) has stated that *Pseudaphritis* *urvillii* could be of direct Gondwanian origin or may be a recent derivative from southern Australian seas but he concluded that "at present there is no way of choosing which and I suspect that we will never know". An undescribed genus and species from this family was recently collected off Wilsons Promontory (Gomon, personal communication) and by the author from Port Davey, South-West Tasmania. This fish appears to be most similar to *Pseudaphritis urvillii* and may assist in elucidating the relationships of that species.

Briggs' (1974) estimate of the number of endemic bovichthyids was correct but was based on incorrect information. *Bovichthys angustifrons*, listed earlier as a southern Australian endemic by Regan (1914), appears to be a synonym of *B. variegatus*.

The family Gobiidae, containing more than 17 Tasmanian species is represented by 8 endemics from 2 genera, *Nesogobius* and *Tasmanogobius*. Other groups with several additional provincial endemics include the families Atherinidae (3 species), Syngnathidae (2 species) and Antennariidae (2 species) but the families Mordaciidae, Torpedinidae, Urolophidae, Clupeidae, Scorpaenidae, Platycephalidae, Labridae, Bothidae, Pleuronectidae and Monacanthidae each contains a single cool temperate endemic.

Last, Scott and Talbot (in press) describe 465 species from Tasmanian waters but the checklist of those occurring in this region now contains about 550 species. There is no recent checklist of Victorian fishes, however, the number of species occurring in the cool temperate province could exceed 600. Recent additions to the Tasmanian checklists, in common with New Zealand lists (McDowall, 1978), have been mainly of wide-ranging species.

Fulton (1979) recognised 25 species as indigenous to freshwaters of Tasmania, including the migratory species and the estuarine species *Pseudaphritis urvillii* and *Retropinna tasmanica*. Endemic species comprise 52% of this fauna and about 3% of the total Tasmanian fish fauna (based on the current checklist).

Briggs (1974) has suggested that endemism in the Maugean Province is 10 - 30% and is variable for each group. The true value is certainly closer to the lower end of this range; about 4% within the Tasmanian fauna and 8% within the provincial fauna. In summary, endemism is more pronounced within the cool temperate marine fauna than within the Tasmanian marine fauna. This is supportive evidence for a Maugean fish fauna.

The total endemism, combining marine and freshwaters of Tasmania, is about 6%. Moreland (1959) approximated 29% for the New Zealand fauna with a marine component of 22%. McDowall (1978), referring to this marine component, maximised endemism at 15% and stated that the New Zealand fauna was not isolated or distinctive but was largely influenced by elements of the world fauna. In comparison, the Tasmanian fauna, particularly the marine components, are certainly less isolated and less distinctive and are more closely associated with the faunas of mainland Australia.

CHAPTER 8

GENERAL DISCUSSION

Estuaries and bays are important fishing grounds and nursery areas for fish (e.g. Lenanton, 1977) but, because they are generally close to centres of human population, they are vulnerable to modification and must be properly managed. An understanding of the physical and biological features of these habitats is an important prerequisite for the planning of management strategies. The complexity of habitat types represented, their uniqueness and variability and the characteristics of their floras and faunas are all important.

The most detailed environmental studies of coastal systems in cold temperate parts of Australia have been completed in Victoria (e.g. Anonymous, 1973; Shapiro, 1975). Although no equivalent studies have been attempted in Tasmania, a summary of coastal features has recently been completed by the Tasmanian Conservation Trust (Goldin, 1980). This detailed work concentrated mainly on terrestrial features of the shore lands and much of the content relating to the subtidal features are based on generalisations of environmental conditions occurring on mainland Australia (i.e. Anonymous, 1977). Nevertheless, when used in conjunction with the more aquatically orientated summary given in Section 4:3, these studies provide a satisfactory basis for future management planning.

The long Tasmanian coastline contains a diverse array and variable distribution of sedimentary habitat types which possess major features that are unique to temperate regions of Australia. Whereas most of mainland Australi is arid, estuaries of western and southern Tasmania have large discharges and low average salinities. Different climatic and geological regimes on the eastern coast are mainly responsible for the more saline estuaries found in this area.

Tasmanian estuarine systems can be classified into a wide range of types including lagoons, bay estuaries, tidal rivers and creeks and a series of closed estuaries and coastal lakes. Consequently, a general classification of Australian estuaries proposed by Rochford (1959b) has limited application in this region. In discussing the classification of estuaries, it is important to consider that some systems are transitory between types. All are in the process of long term evolution (on a geological time scale) whereas others, such as closed systems, are generally modified annually and probably evolve more rapidly. Roy (1982) has made similar observations on estuaries in New South Wales. Intermediate forms are likely to be the rule rather than the exception.

The distributional patterns of aquatic plants in shore zone habitats are equally complex. Contrary to Goldin (1980), the mangrove, *Avicennia marina*, does not occur in Tasmanian waters. It is mainly a tropical and warm temperate plant with a southernmost distribution of Western Port Bay (Shapiro, 1975). Mangroves are known to be important habitats for fish (Field, 1981), hence their absence from this region may have a significant effect on the distributions of some species.

Seagrasses, *Amphibolis antarctica* and *Posidonia australis*, the latter of which forms extensive habitats on the Australian mainland (Bell, 1980), are rarely found south of Bass Strait. These habitats in the sheltered marine bays of southern Tasmania are dominated by another species, *Heterozostera tasmanica*. Some fishes found amongst *Amphibolis* and *Posidonia* were never collected from *Heterozostera* beds. The ranges of these fishes could be limited by the absence of a suitable seagrass habitat type or alternatively, could have uncorrelated coinciding extra-limital distributions with the seagrass type. In the latter case, the physical characteristics of the environment are likely to be the controlling factor. Regional studies of the preferences of fish for specific seagrass types appears to be a neglected field but Pollard (1982) found that, on a wide geographic scale, family relationships were determined mainly by zoogeographical factors rather than seagrass type.

The spectrum of sedimentary habitats of the shore zone ranges from the sheltered upper reaches of the estuaries to the turbulent, euhaline surf zone of exposed beaches. Of the fish species occurring throughout this range, the majority have restricted distributions within these habitats. Associations representing an estuarine fish community, a sheltered beach community, an exposed beach community and elements of a coastal freshwater fish community were isolated during the study.

The estuarine community of the Great Swanport Estuary could be divided into two assemblages. A middle and upper estuary assemblage was dominated by true estuarine species. The dominant elements in the lower estuary, however, were amongst those selected by the B.D.A. analysis as being diagnostic of a sheltered beach fish community. This supports earlier suggestions of a close similarity in the faunas of sheltered beaches with those of euhaline or polyhaline estuaries (i.e. many open lagoons and bay estuaries).

Habitat complexity versus diversity and the ecological roles of species is a perplexing topic which raised several questions in this study. For example, resident or indicator species are useful in identifying particular community types (Krebs, 1978) but, in these fish communities, the incidental species or transients had the most pronounced effect on species richness.

Species richness was higher over seagrasses than over unvegetated sediments. Briggs and O'Connor (1971) have made similar observations and attributed the presence of additional cover over vegetated bottoms as a possible reason. Furthermore, the low diurnal density of species over sediments at Nutgrove Beach (see Chapter 5) compared with those living amongst seagrasses at the entrance of the Great Swanport Estuary (see Chapter 6) supports this argument.

During the day, the fauna of Nutgrove Beach was poor in both species and abundances of individuals but at night became much more complex and changed in composition. This nocturnal component of residents and transients was not evident in any of the sampling sites at Nine Mile Beach or in the Swanport Estuary. In the former case, the complexity of the fish fauna appears to be more closely related to temporal characteristics than to microhabitat complexity.

The assemblage of species moving onto the beach at night contains elements of an offshore fauna (Last and Harris, 1981). The beach is close to deep water (i.e. the main channel is about 25 m deep and is situated less than 1 km from the beach) allowing deep water fishes to penetrate the estuary and migrate into shallow water. In comparison, species living in similar depths of Great Oyster Bay would have to migrate almost 15 km to reach the entrance of the Swanport Estuary. Hence the sizes of ecotones (*sensu* Clark, 1977) are probably important in determining the community composition of mobile animals such as fishes.

How important are ecotone sizes in controlling the diel characteristics of fish communities? Species that migrate in and out of a particular habitat type in a daily cycle must rely partly on a second habitat type.

By necessity, species must be either very mobile or must alternate between closely positioned habitats (i.e. with a narrow ecotone). Temporal changes in composition and dominance of species across an ecotone could cause the faunal changes observed by various workers who have examined periodicity of fishes. It is hypothesized that ecotone size is an important factor in determining temporal patterns of diversity in fishes.

The non-random emigration and immigration of species have negative and positive effects respectively on the faunal complexity of the habitat. What diversity is lost temporarily from one community is gained by another. There is unlikely to be any value in trying to derive a general principle governing temporal complexity of particular habitat types. Instead, a regional understanding of the temporal patterns of migration of the main species between overlapping communities, taking into consideration ecotone size, is probably a more appropriate means of assessing faunal changes within communities.

The fish faunas of sedimentary habitats of the Tasmanian shore zone are also influenced by faunal elements from other coastal communities. Reef fishes are found occasionally in the narrow ecotone between beaches and rocky habitats. Similarly, freshwater and estuarine species are not uncommon in marginal areas of beaches.

The faunal composition of fishes within a major habitat may be greatly affected by the proximity of different macrohabitats. After storms or during die off, seagrasses often form dense floating mats near the surface. These masses, which contain several passive weed-dwelling species such as pipefishes (syngnathids) and weedfishes (clinids), often remain in normally unvegetated habitats for extended periods. Although this 'drift' element is not part of the resident beach fauna, it forms a significant component of the fish community in some areas.

Exposed beaches have simple resident faunas consisting of only few species that are generally low in abundance. Floating kelp masses, uprooted from reef habitats during storms, may wash into the shore zone of exposed beaches where they are decomposed. On very exposed beaches this kelp is stranded by wave action above the high tidal mark and decomposition appears to be performed mostly by terrestrial organisms. In contrast, these masses, when accumulated off semi-exposed beaches, may remain subtidally for several weeks. They have, in addition to a small element of passive reef-dwelling species (mainly syngnathids and clinids), high abundances of epifaunal invertebrates and intertidal decomposers (mostly amphipods). Juvenile *Sillago bassensis* and *Contusus* spp., which ingest large quantities of invertebrates, are often abundant during this period. Their occurrence in this habitat was correlated with the presence of the algal drift community, but the mechanisms of algal decomposition and the role of both resident and transient fishes in unknown. Exposed beach fishes and algal drift communities have received little attention from ecologists in Australia.

Estuaries, in contrast to exposed beach habitats, in this region are complex habitats. Their faunas are influenced mainly be the presence of marine migrants which have distributions in estuaries determined largely by salinity. A relationship for representing the numbers of species, in relation to salinity, within an estuary has been presented by Remane (1934). Bayly (1975) commented on the lack of satisfactory data avaialable to test the validity of this curve (Fig. 8:1a) and noted that the proportion of true estuarine species appeared to be lower for fish than for plankton or benthos in Australian estuaries.

A species number/salinity curve for fishes in Tasmanian estuaries (Fig. 8:1b,c), including freshwater, estuarine and marine euryhaline

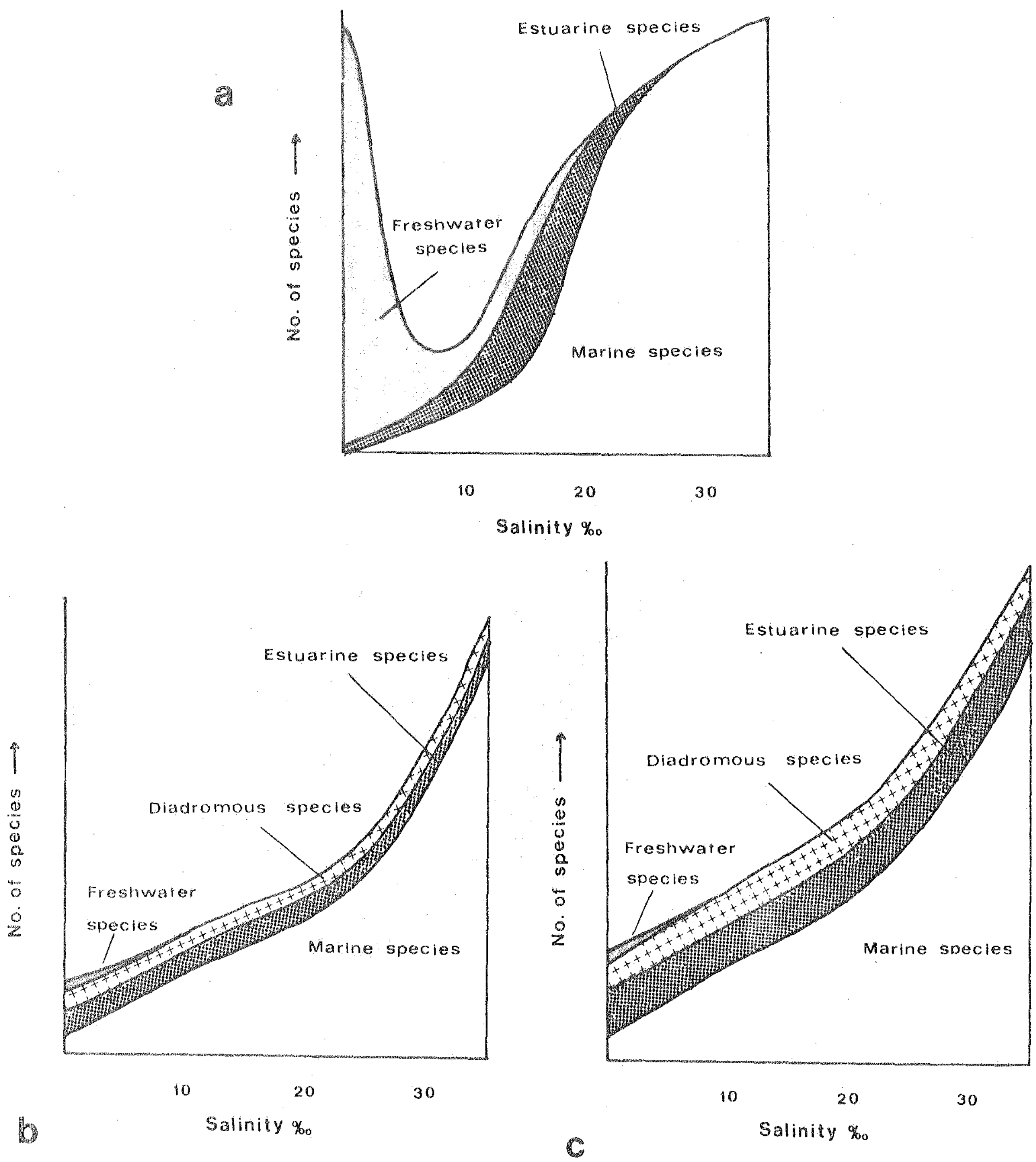


Figure 8:1 Variation in the total number of species, and in the species representation of different faunal components, in relation to salinity within an estuary.

a. based on the classical curve of Remane (1934) - extracted from Bayly (1975).

b. based on a checklist of fishes occurring in Tasmanian estuaries and salinity/fish distribution data obtained in this study.

c. based solely on salinity/fish distribution data obtained in this study.

components, resulted in a very different relationship from the system proposed by Remane. Tasmania, like mainland Australia, has a relatively impoverished freshwater fish fauna (McDowall, 1981) and this was depicted by the much smaller size of this component. Day (1981c) found a correspondingly small freshwater element amongst the macrobenthos of South African estuaries.

Remane's true estuarine component, which includes those species that are totally restricted to brackish waters, in inapplicable for fish in this region. Twelve species live, breed or are most abundant in estuaries (see Table 8:1) and can be regarded as estuarine species but, with the possible exception of *Retropinna tasmanica*, all are found in both freshwater and marine environments.

Another category, the diadromous component, consisted of 9 native species which fit none of Remane's categories. In common with estuarine species they are typically euryhaline III. Remane's curve was constructed to include the whole brackish water biota of estuaries. Consequently, its overall applicability to the Tasmanian region is totally dependent on the distribution of invertebrates in these systems.

The large number of euryhaline III species in Tasmanian estuaries was responsible for a higher proportion of marine euryhaline species in the olighaline sector of the graph.

The euryhaline marine fish component has been the subject of detailed study in northern and central America (Gunter, 1942; 56) where 150 species have euryhaline III status. The known occurrence of fish in Australian estuaries have been summarized by Bayly (1975), and Parker (1980) has listed 33 southeastern Australian marine fishes that may enter freshwater.

An inventory of the major euryhaline fish species occurring in brackish waters in Tasmanian is presented in Table 8:1; for a complete list of those recorded from Tasmanian estuaries see Appendix 7:3. Of the 81 euryhaline

Table 8:1 : Native fishes with euryhaline distributions in Tasmanian estuaries.

(1) Euryhaline III marine species	
Engraulis australis	*Nesogobius* sp. 2
Atherinosoma presbyteroides	*Ammotretis rostratus*
Gymnapistes marmoratus	*Rhombosolea tapirina*
Arripis trutta	*Acanthaluteres spilomelanurus*
Myxus elongatus	*Meuschenia freycineti*
Aldrichetta forsteri	
(2) Estuarine species	
Retropinna tasmanica	*Favonigobius tamarensis*
Atherinosoma microstoma	*Pseudogobius olorum*
Urocampus carinirostris	*Tasmanogobius* sp. 3
Macquaria colonorum	*Tasmanogobius lordi*
Acanthopagrus butcheri	*Amoya bifrenatus*
Pseudaphritis urvillii	*Cnidoglanis macrocephalus*
(3) Anadromous species	
Geotria australis	*Lovettia sealii*
Mordacia mordax	
(4) Catadromous species	
Anguilla australis	*Anguilla reinhardtii*
(5) Other diadromous species	
Protrotroctes maraena	*Galaxias brevipinnis*
Galaxias maculatus	*Galaxias truttaceus*
(6) Euryhaline freshwater species	
Galaxias cleaveri	*Philypnodon grandiceps*
Nannoperca australis	*Favonigobius* sp.

marine species only 8 were listed by Bayly (1975) as occurring in Tasmanian estuaries. Similarly, only 2 Tasmanian marine species, *Girella tricuspidata* and *Enoplosus armatus*, were reported by Parker (1980) to enter freshwater. Lake and Fulton (1981) have recorded *Rhombosolea tapirina* from freshwater whilst Thomson (1980) accredited *Myxus elongatus* and *Aldrichetta forsteri* with entering coastal streams. *Engraulis australis, Atherinosoma presbyteroides, Gymnapistes marmoratus, Arripis trutta, Nesogobius* sp. 2, *Ammotretis rostratus, Acanthaluteres spilomelanurus* and *Meuschenia freycineti* can hereby be added to the list of marine species transient in freshwater.

Bayly (1975) recognised only one true estuarine species, *Acanthopagrus butcheri*, from Australian estuaries although *Cnidoglanis macrocephalus* was unique to a euryhaline marine and estuarine category. The major criterion for distinguishing true estuarine species from those of other categories is often based on their obligatory occurrence in brackish habitats. This provision is inapplicable to all of the 12 Tasmanian estuarine species, including *Acanthopagrus butcheri*. Of these, only *Urocampus carinirostris* and *Tasmanogobius* sp. 3 have not previously been found in freshwater and only *Retropinna tasmanica* has not been reported from the sea. However, based on life histories and distributional data these species are typically estuarine in habit.

A group of diadromous fishes can be further subdivided into anadromous and catadromous components. Whereas anadromous species migrate from the sea upstream into freshwater to spawn, the classification of catadromous species is less distinct. Gunter (1956) listed only the eel, *Anguilla rostrata* (Le Sueur), as the only catadromous species found in North American estuaries. Related Tasmanian species, *Anguilla australis* and *A. reinhardtii*, also migrate from freshwater and spawn in the open ocean. Anomalous fishes, notably *Prototroctes maraena* and some galaxiids, have a marine phase in their early life histories but the seaward spawning migration of adults may possibly terminate in the brackish regions of estuaries.

A category of euryhaline freshwater fishes, which is represented by only 4 species in this region, was ignored by Bayly (1975).

Gunter (1956) noted that the percentage of euryhaline III species is greater for the lower fishes than for advanced fishes. Lower teleosts (*sensu* Gosline, 1971) comprise 36% of this component in Tasmanian estuaries although they form only 11% of the total number of teleosts found in these habitats. Similarly, in agreement with the situation in North America, all diadromous species are lower fishes. Gunter (1956) explained these phenomena on the basis of ecological, physiological, paleontological and evolutionary criteria.

Members of the Gobioidea or gobies represent 30% of the higher teleostean component. Gunter (1956) made similar observations on American fishes and added that this group had been more actively engaged in colonising freshwater than any other fish group in the recent era.

The concept of habitat dependence of juvenile fishes poses some questions that require further discussion. How many juveniles have to be present before a habitat is recognisable as a nursery and how can the dependence of a species on a habitat be assessed?

A periodic aggregation of 0+ age group fishes in a particular habitat implies that the habitat is acting as a nursery area for that species. However, such observations do not qualify the importance of this nursery area because other habitats could be the major habitats for juveniles of the species. For example, juvenile *Arripis trutta* use sheltered beaches and estuaries as secondary nursery areas but the main populations are concentrated off exposed beaches. Thus the number of species using a habitat as a major nursery area must be known before the importance of the habitat as a nursery can be accurately assessed. Also a knowledge of alternative nursery areas is a prerequisite for determining which habitats constitute major nurseries. Unfortunately such basic information is generally unavailable and circumstantial evidence forms the basis of many habitat evaluations.

Wallace and van der Elst (1975) have commented on the difficulties in assessing the level of dependence of estuarine juvenile phases in the life histories of fishes. They highlighted problems encountered when sampling juvenile fishes with different ontogenetic habitat preferences or wide-spread bathymetric distributions. A similar argument can be applied to many juvenile fishes occurring in other coastal sedimentary habitats.

Wallace and van der Elst (1975) have concentrated on the question of assessing whole or partial dependence upon an estuarine juvenile phase. A more important question orientated to environmental management and habitat conservation deals with habitat independence. Could species, in the absence of major nursery areas, use alternative areas or even new nursery grounds to successfully complete their life cycles? Knowledge of the inability of species to be adaptable in this way is essential in establishing their habitat dependence. No studies known to the author have attempted to examine this aspect, hence current assessments have been inferential (Wallace and van der Elst, 1975) or were based on 'facultative dependence'.

Pollard (1976) has defined estuarine dependence in a facultative manner. Dependent species are those "in which the majority of the population inhabits an estuarine environment during at least one phase of its life history." Bell (1980) proposed a convenient way of categorising fishes according to their level of estuarine dependence. His groups were as follows:

a. all life history stages entirely estuarine dependent;
b. new recruits and juveniles entirely estuarine dependent, but adults only partially dependent for feeding requirements;
c. only new recruits and juveniles estuarine dependent, adults leaving the estuary permanently;

d. all life history stages only partially dependent for feeding and/or shelter.

Bell's classification can be applied to many Tasmanian estuarine fishes but there are a few problems with its general application. A separate category is required for migratory fish such as *Anguilla* spp., *Mordacia mordax, Geotria australis* and *Lovettia sealii.* These species spend most of their life cycles outside estuaries but depend on them as a migratory pathway. Their use of estuarine habitats may be more obligatory than the requirement imposed on many 'category a' species. For example, *Atherinosoma microstoma* is most abundant in estuaries and fits the criteria of 'category a'. Despite this, it can also breed in closed systems that vary in salinity from freshwater to hypersaline. Hence its dependence on estuaries is facultative. A similar argument is applicable to *Acanthaluteres spilomelanurus, Meuschenia freycineti, Stigmatopora nigra* and *Gymnapistes marmoratus* which also feed, grow,and appear to spawn, both in estuaries and in sheltered marine habitats.

Amoya bifrenatus, Retropinna tasmanica, Urocampus carinirostris, Acanthopagrus butcheri, Pseudaphritis urvillii, Pseudogobius olorum, Favonigobius tamarensis and the *Tasmanogobius* spp. are typical 'category a' species. Adults of *Girella tricuspidata,* which spawn outside estuaries in New South Wales (Bell, 1980), occur in small populations in some isolated lagoons along northeastern Tasmania but are mostly absent from adjacent marine habitats. Juvenile fish collected from these estuaries during summer may have been derived from the resident estuarine populations. Alternatively, they could have been transported into the estuary by south-bound currents as larvae from parent populations occurring along the coast of mainland Australia. No data are available on gonad development in adult *Girella* from Tasmanian estuaries.

Six species can be classed as 'category b' and these include 3 commercial species, *Aldrichetta forsteri, Rhombosolea tapirina* and *Ammotretis rostratus*. *Mugil cephalus* and *Myxus elongatus* rarely occur in this region whilst the life history of *Prototroctes maraena* has not been fully determined.

No species could be attributed to Bell's 'category c'. *Chrysophrys auratus* and *Sillaginodes punctata* are dependent on estuarine habitats as juveniles but the adults are generally found in marine habitats (Lenanton, 1977; Bell, 1980). Although rare, these species occur only as adults in Tasmanian estuaries.

The remaining 190 species recorded from Tasmanian estuaries have life history stages that are only partly dependent for feeding and/or shelter (i.e. 'category d').

Habitat dependence of beach and bay fishes is even more difficult to assess. Several species occur in these habitats as juveniles but are caught by fishermen on the offshore areas of the continental shelf as adults (e.g. *Platycephalus bassensis, Rhombosolea tapirina* and *Ammotretis rostratus*). In most cases the abundances of their juveniles in offshore habitats are unknown. As for estuaries, it is mostly difficult to determine whether the dependence of juveniles on beach habitats is facultative or obligatory. Because of their widespread distribution on sedimentary habitats, for the specific examples given above, dependence in likely to be facultative.

A few small species are probably dependent on sheltered beach habitats throughout their life histories. These include some gobiids (*Favonigobius lateralis, Tasmanogobius* sp. 1, *Amoya frenatus, Nesogobius* sp. 2, *Nesogobius* sp. 7) and atherinids (*Atherinason esox, Atherinason* sp.). Other beach-dwelling gobies, such as *Nesogobius pulchellus, N. hinsbyi*, and *N.* sp. 5, have also been collected from reef habitats (Last, unpublished data; J.B. Hutchins, personal communication). Underwater observations of these species on reefs, however, suggest that their occurrence in these habitats may be incidental. Most individuals occurred on small sand patches near the reef fringe and they were rarely observed on the main area of the reef which is devoid of sediments.

Based on current knowledge of well-studied species, habitat dependence remains difficult to ascertain. *Hyporhamphus melanochir* is most common in sheltered beach habitats during summer and autumn where it is seined by commercial fishermen. South Australian populations spawn from October to March but although initially suspected of spawning inshore over seagrass, catch data suggests that breeding may occur offshore (Ling, 1958). Juvenile fish occur in the shore zone for most of the year in South Australian waters whereas in Tasmania they tend to emigrate from these habitats in winter and spring. Ling (1958) reported *Hyporhamphus melanochir* occurring up to 100 miles offshore but did not record the time of year when these observations were made. Additional information is required on the offshore behaviour of this species.

Atherinosoma presbyteroides, the most abundant fish found in sheltered beach habitats, also use estuaries as nursery and feeding grounds. Consequently, its dependence on beaches is likely to be facultative.

Some fishes exhibited a strong preference for seagrass habitats and a dislike for unvegetated substrates (see Section 4:5:2). These included the pipefishes (*Syngnathus phillipi* and *Stigmatopora argus*), weedfishes (*Cristiceps australis* and *Heteroclinus perspicillatus*) and rock whitings (*Neoodax semifasciatus* and *N. balteatus*) which have also been collected from rocky habitats (Edgar, 1981; Hutchins, unpublished data). Their habitat dependence may be related to the availability of vegetation rather than to the presence of seagrasses. In this situation, kelps provide a supplementary habitat on reefs.

A single species, *Crapatalus arenarius*, appeared to be dependent on exposed beach habitats. These areas are also used as nurseries and occasional feeding grounds for the adults of *Arripis trutta, Ammotretis liturata, Contusus richei* and *C.* sp. whose main populations occur offshore (Tasmanian Fisheries Development Authority, unpublished data; Stanley, 1980). The juveniles of *Crapatalus arenarius* and *Ammotretis liturata* were only abundant in the surf zones of beaches and may be more dependent on these habitats as nurseries than immature *Arripis trutta* which are widespread in all sedimentary habitats of the shore zone.

In addition to being major nursery areas, estuaries are important fishing grounds in mainland Australia. Local estuaries appear to be much less important as commercial fishing grounds than similar areas of mainland Australia, although reliable figures for fish production of most species in Tasmanian are currently unavailable. Reasonable catch statistics are available for distinctive species (e.g. *Aldrichetta forsteri*) but where 2 or more similar species are invovled (e.g. *Pseudophycis* spp., *Platycephalus* spp.), catch data has usually been combined.

The 1977-78 preliminary production figures, issued by the Australian Bureau of Statistics, list the total fish landings for Tasmania as 3,105 tonnes live weight (Anonymous, 1979b). Yellow-eyed mullet, *Aldrichetta forsteri*, was the only species listed that is caught commercially in estuaries. The catch, a mere 3 tonnes, is less than 0.1% of the total fish catch. A 408 tonne portion of miscellaneous species possibly contains some production from species caught in estuaries such as red cod (*Pseudophycis bachus*), silver trevally (*Caranx georgianus*), greenback flounder (*Rhombosolea tapirina*) and shortfin eels (*Anguilla australis*), however this proportion is likely to be small in comparison with production from species caught in marine areas such as deepsea trevalla (*Hyperoglyphe antarctica*), ling (*Genypterus blacodes*), blue grenadier (*Macruronus novaezelandiae*), gemfish (*Rexea solandri*), warehou (*Seriolella brama*) and bastard trumpeter (*Latridopsis forsteri*). Even using such crude information sources, commercial production from Tasmanian estuaries in considerably lower than that of local marine environments. Fishing effort is much less intense in estuaries and this is probably closely related to the lower abundance and number of suitable commercial species in this environment.

Johnston (1883) listed 4 major marketable species commonly caught in the shore zone areas around Tasmania: *Ammotretis rostratus, Rhombosolea tapirina, Hyporhamphus melanochir* and *Aldrichetta forsteri*. These species, along with *Pseudophycis bachus* and *Platycephalus bassensis*, are the only common marine species occurring as adults in most Tasmanian estuaries. Of these, only *A. forsteri* and to a lesser extent *R. tapirina* and *H. melanochir* are present in good commercial quantities. *Lovettia sealii* once formed a 500 tonne per year fishery (Blackburn, 1950) but the species is now much less abundant and the fishery has been closed since 1974 to allow populations to recover (Scott, 1971; Fulton, 1979).

Fish such as snapper (*Chrysophrys auratus*), tailor (*Pomatomus saltator*), King George whiting (*Sillaginodes punctatus*) and dusky flathead (*Platycephalus fuscus*), are important commercial species in many estuaries of mainland Australia. Apart from being good food fishes, these species, which attain a large maximum size and are also important to recreational fisheries, rarely occur in Tasmanina waters. Tasmanian estuaries, in comparison, harbour few species that are of value to anglers. The bream (*Acanthopagrus butcheri*) is the major sport fish in many estuaries of eastern Tasmania but is rarely caught in systems along the West and North-West Coasts. *Aldrichetta forsteri* was once caught in large quantities by anglers in the major estuaries (Johnston, 1883) but is now seldom caught in quantity other than in seine nets. No information is available on the recreational catch of salmon (*Arripis trutta*), however, it appears to be small and seasonal.

A few marine species are caught seasonally by anglers in small quantities in the Derwent and Tamar Estuaries. These include adults of *Trachurus* *declivis, Sphyraena novaehollandiae, Pseudophycis bachus, Platycephalus bassensis,Sillago bassensis* and juveniles of *Macruronus novaezelandiae, Caranx georgianus, Nemadactylus macropterus* and *Seriolella brama.*

There are several problems with present legislation concerning the management of fish stocks in Tasmanian estuaries. Jurisdiction over esturies is currently divided between 2 Government instrumentalities. The Tasmanian Fisheries Development Authority (T.F.D.A.) is responsible for management of living resources in the sea, including tidal waters, while the Inland Fisheries Commission (I.F.C.) regulates stocks in inland waters (Fisheries Act, 1959).

The Fisheries Act (Part 1, Section 3a) stipulates that tidal waters comprise the sea and any waters that are subject to tidal flow at ordinary spring tides other than the waters of a river above its seaward limit. Hence the normal seaward boundary would be situated at the junction of the river and the sea, harbour or bay at low water of ordinary spring tides. Special provisions were incorporated into the Act to accommodate 13 bay estuaries or tidal rivers which presumably were considered to be penetrated frequently by saline water. Special boundaries have been stipulated for these estuaries (Schedule 3, Part 2). Consequently, inland waters were defined as comprising all waters other than tidal waters.

Boundary positions have been the subject of recent dispute which, based on the findings of this study, are not unfounded. These boundaries have been selected without prior research to assess their validity and in many cases are not even based on convenient landmarks. Instead, their proponents have used small posts located on shore to represent seaward boundaries which are totally devoid of scientific basis.

The present boundaries are artificial biologically and do not account for regional variation of estuarine types. Many tidal estuaries are predominantly freshwater whereas large estuaries and lagoons are frequently penetrated to the first riffle by brackish water. The latter systems remain euhaline or polyhaline for long periods and have fish faunas resembling those of sheltered beaches. Furthermore, the legislation does not allow for the diversity of estuarine types found in this region. Several beach and bar-dammed systems (e.g. Big Lagoon, Dianas Basin, Wrinklers Lagoon) are deemed by the Act to be outside the ebb and flow of tides (Schedule 3, Part 1). These systems, which may remain open to the sea for extended periods, are generally saline and mostly support large populations of euryhaline and estuarine fishes.

The seaward boundaries of many of the 13 estuaries mentioned earlier do not represent reasonable tidal limits. Deep systems, such as the Tamar and Derwent Estuaries, and the Swan River are mostly stratified and saline water extends upstream well beyond the recognised seaward limit. The Act also fails to acknowledge that several other large embayments, such as Port Davey, Macquarie Harbour, Georges Bay and Ansons Bay, are large estuaries. Presumably these fall into a category of harbours and bays.

Several marine fishes occur frequently in estuaries and 36 of these are caught commercially in the sea. Meanwhile, the number of freshwater species entering estuaries is low and none of these is commercial.

Both Tasmanian fisheries bodies are basically concerned with management of fish stocks. Since estuaries, which are comparatively unimportant to freshwater fisheries, are important nurseries for many juvenile marine fishes they should be managed in conjunction with coastal fisheries. The greatest area of potential conflict over resources exists within the management of migratory species. Eels (*Anguilla* spp.) are caught in freshwater and estuarine habitats and the catch information is handled independently by each institution.

More cooperation , possibly resulting in joint management of estuarine resources, is required between these bodies. Alternatively, the T.F.D.A.

should assume total responsibility for the management of fish resources in marine environments and the coastal watershed while the I.F.C. attends to the limnetic habitats of the inland lakes and coastal floodplains (see Section 4:3:1). Boundaries could be located at the most seaward riffle zone, ascertained independently for each estuary or modelled on the basis of coastal regions.

CHAPTER 9

SUMMARY AND CONCLUSIONS

1. Sedimentary habitats of the shore zone and coastal watershed include beaches, estuaries and coastal lakes. In Tasmania, these types are geographically variable and highly complex. Factors responsible for determining their environmental features include geomorphological, climatic, hydrological and botanical characteristics. The main features of each and their distributions in this region have been described.

2. Three general environment types were isolated in the shore zone and coastal watershed: a closed and semi-closed estuarine environment; an open estuarine environment; and a beach environment. Although this classification may be incomplete, it is useful as a basis for future studies and provides a guideline for present management programming in the interim period.

3. The closed and semi-closed estuarine environment contains a complex of coastal lakes, bar-dammed lagoons and rivers and beach-dammed lagoons. The distributions of these habitats, like those of other environments, are concentrated in particular areas of this region.

4. Open estuarine systems were identified by open lagoons, bay estuaries and tidal rivers and creeks. Lagoons are concentrated mainly on the eastern coasts, whereas tidal rivers occur mainly along the Bass Strait Coast and in the West and South.

5. Three main habitat types were recognised in the beach environment: a sheltered beach habitat; a semi-exposed beach habitat; and an exposed beach habitat. While these types occur as a continuum from very sheltered to very exposed beaches, specific types are mostly distinct.

6. Soft-bottom habitat types of the Tasmanian shore zone do not represent clearly defined biotopes for fishes and their boundaries are often difficult to delimit. Instead, fish species occurring in these environments can be more appropriately assembled into associations.

7. Four broad associations could be identified from the fish fauna of soft-bottom habitats of the shore zone of Tasmania. These include a small coastal freshwater assemblage, an estuarine assemblage, a sheltered beach assemblage, and an exposed beach assemblage. Associations often exhibited considerable overlap and 7 species were ubiquitous to these habitats.

8. The coastal freshwater fish assemblage includes only 4 euryhaline species which rarely occur in these habitats. A group of 9 migratory species (i.e. diadromous, catadromous and anadromous forms) also apply to this category: dominant species include *Galaxias maculatus, G. truttaceus* and *Anguilla australis*.

9. An estuarine assemblage is identified mainly by *Atherinosoma microstoma, Acanthopagrus butcheri, Pseudaphritis urvillii, Pseudogobius olorum* and *Favonigobius tamarensis*. The relative importance of these species and their distributions within estuaries varies intra-regionally in accordance with the wide range of estuary types found around Tasmania. These species are mostly concentrated in the upper areas of euhaline estuaries and in the lower areas of oligohaline estuaries but are widely dispersed in systems that are typically mesohaline or polyhaline.

10. A sheltered beach assemblage contains the largest number of species of the faunal types discussed. The composition of species is most complex amongst seagrasses. These habitats, which are fished mainly for garfishes (*Hyporhamphus melanochir*), also act as important nursery areas for several commercial species including *Ammotretis rostratus*, *Rhombosolea tapirina*, *Platycephalus bassensis*, *Aldrichetta forsteri* and *Neoodax semifasciatus*.

11. The exposed beach assemblage was small and its diversity appeared to vary inversely with increasing exposure. Exposed beaches, while of some value to recreational fisheries, are not important commercial fishing grounds. They may be major nursery areas, however, for *Arripis trutta* and *Ammotretis liturata* which are of commercial value in this region. *Crapatalus arenarius* is an indicator of this community type.

12. Those species ubiquitous to sedimentary habitats of the shore zone include *Aldrichetta forsteri*, *Ammotretis rostratus*, *Arripis trutta*, *Atherinosoma microstoma*, *Atherinosoma presbyteroides*, *Nesogobius* sp. 2 and *Rhombosolea tapirina*. However, these species did exhibit clear preference trends for particular habitat types.

13. Ecotone size appears to be an important factor in determining the amount of overlap between fish communities in coastal habitats. Overlap between estuarine and coastal fish assemblages in marine habitats occurs frequently in marginal areas and is more pronounced in sheltered beach habitats than in exposed beach habitats.

14. Substrate and salinity preference trends were evident amongst soft-bottom shore zone fishes. In addition, almost half the species sampled migrated into the intertidal zone and the 7 main migrants were all widespread species.

15. Fishes living over a sandflat in the Derwent Estuary exhibited diel and seasonal changes in abundance and diversity. Numbers of species and individuals and the number of large fish increased at night resulting from an immigration of fishes from deeper parts of the estuary. This response may be associated with the evasion of predatory elasmobranchs but further research is required to test this hypothesis.

16. Fishes of the sandflat, which exhibited a high family diversity, were represented by many families that are monospecific in this habitat. Of the 50 fish species sampled, 56% were benthopelagic, 40% were benthic and 4% were pelagic. More than half of these species are resident in this habitat throughout the year, although some diel transients occur only on the sandflat in the night or during the day. Seasonal transients consisted of fresh/brackish water invaders during winter and spring and marine invaders during summer and autumn. Transients consist of several marine species and a few estuarine, migratory euryhaline freshwater and anadromous species.

17. Three broad associations were identified amongst 54 fishes occurring in the Great Swanport Estuary and environs. These included a typical exposed beach fish assemblage on the adjacent beach, a lower estuary assemblage which consisted primarily of sheltered beach fishes, and a middle/upper estuary assemblage which was dominated by true estuarine species.

18. A community score, which includes information on abundance, occurrence and fidelity, provided an objective method of determining the major species in the fish assemblages of the Swanport Estuary. Seventeen species were isolated and the following were indicator species: (1) beach assemblage - *Crapatalus arenarius, Arripis trutta;* (2) lower estuary - *Nesogobius* sp. 2,

Ammotretis rostratus; (3) middle/upper estuary - *Atherinosoma microstoma, Pseudaphritis urvillii.*

19. Ten of the 17 major species appear to spawn in estuaries whilst only 1 species spawns off the beach. The main spawning period for most species is late spring, early summer. An influx of juveniles into the estuary is apparent in summer and autumn.

20. Females of 12 species were significantly more abundant in the estuary than males. Sex reversal, differential zygote mortality or differences in the habitat preferences of sexes may be possible causes but the reason for this anomaly has not been elucidated.

21. Fishes of this system and the adjacent beach are mainly primary carnivores and amphipods are the major prey components. There are no large, wholly piscivorous species in the area although a few are secondary predators of juvenile fish and the adults of small species. Few fishes act as detritivores.

22. Although species could be broadly grouped into carnivores, planktivores and omnivores, and further into pickers, grazers and browsers, based on the higher taxa prey compositions, species were largely opportunistic depending on the availability of prey species at each site.

23. Almost 550 fish species are known to occur in the Tasmanian region and, of these, 216 have been recorded from estuaries; a checklist of the latter is presented. Eleven undescribed and 7 previously unrecorded species were included amongst 154 species collected during the course of the sampling programme.

24. The classical curve of Remane for variation in the number of species within an estuary is not applicable to fish in Tasmanian estuaries. The freshwater component is considerably smaller and an additional faunal component, the diadromous component, is prominent.

25. Of those species recorded from Tasmanian estuaries only 32 were found in both limnetic and euhaline waters.

26. Twelve species are truly estuarine. *Retropinna tasmanica, Atherinosoma microstoma, Urocampus carinirostris, Acanthopagrus butcheri, Pseudaphritis urvillii, Favonigobius tamarensis, Pseudogobius olorum, Tasmanogobius* sp. 3, *Tasmanogobius lordi* and *Amoya bifrenatus* are abundant in Tasmanian estuaries but *Cnidoglanis macrocephalus* and *Macquaria colonorum* rarely occur in this region.

27. Eleven marine species frequently inhabit or enter estuaries and occasionally venture into freshwater. These include *Engraulis australis, Atherinosoma presbyteroides, Gymnapistes marmoratus, Arripis trutta, Myxus elongatus, Aldrichetta forsteri, Nesogobius* sp. 2, *Ammotretis rostratus, Rhombosolea tapirina, Acanthaluteres spilomelanurus* and *Meuschenia freycineti*.

28. Euryhaline migratory fishes found in Tasmanian estuaries include anadromous, catadromous and diadromous species. Three species, *Geotria australis, Mordacia mordax* and *Lovettia sealii*, migrate through estuaries from the sea to breed in freshwater. Two eels, *Anguilla australis* and *A. reinhardtii*, are catadromous. Three galaxiids, *Galaxias maculatus, G. brevipinnis* and *G. truttaceus*, and the grayling, *Prototroctes maraena*, are diadromous.

29. The fish faunas of temperate estuaries exhibit similarities in family composition that are determined by their latitudinal and regional characteristics. Northern and Southern Hemisphere faunas are distinct whilst those of the North Pacific are separable from those of the North Atlantic. A more detailed analysis of generic relationships awaits the completion of revisionary studies in other regions.

30. The Tasmanian estuarine fish fauna is dominated by coastal marine species of which three-quarters are endemic to Australian waters. A Maugean element is dominant within the fauna although relationships to Flindersian, Peronian and New Zealand faunas are evident. Antarctic and tropical elements are poorly represented.

31. Endemism of the whole Tasmanian fish fauna is about 6%. The marine fauna is closely associated with the faunas of mainland Australia and endemism in this component is nearer 4%.

32. Tasmanian estuaries, although less important as fishing grounds than in other parts of Australia, are important nursery areas for marine fish. Juveniles of 36 species, some of which are offshore demersal fishes that rarely occur in shallow water in warmer waters, occur in these systems. In comparison, few commercial freshwater species are found in estuaries either as adults or juveniles. Estuarine fishes are more closely associated with coastal marine fisheries than with freshwater fisheries, consequently current legislation granting jurisdiction over most of these systems to the Inland Fisheries Commission seems inappropriate. It is recommended that these estuaries should be managed jointly by both Government instrumentalities. If this is not feasible then, based on the structure of the fauna to be managed, the most appropriate body would be the Tasmanian Fisheries Development Authority (Sea Fisheries).

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VOLUME 2

APPENDICES

CONTENTS

VOLUME 2 : APPENDICES

APPENDIX

TO CHAPTER 4

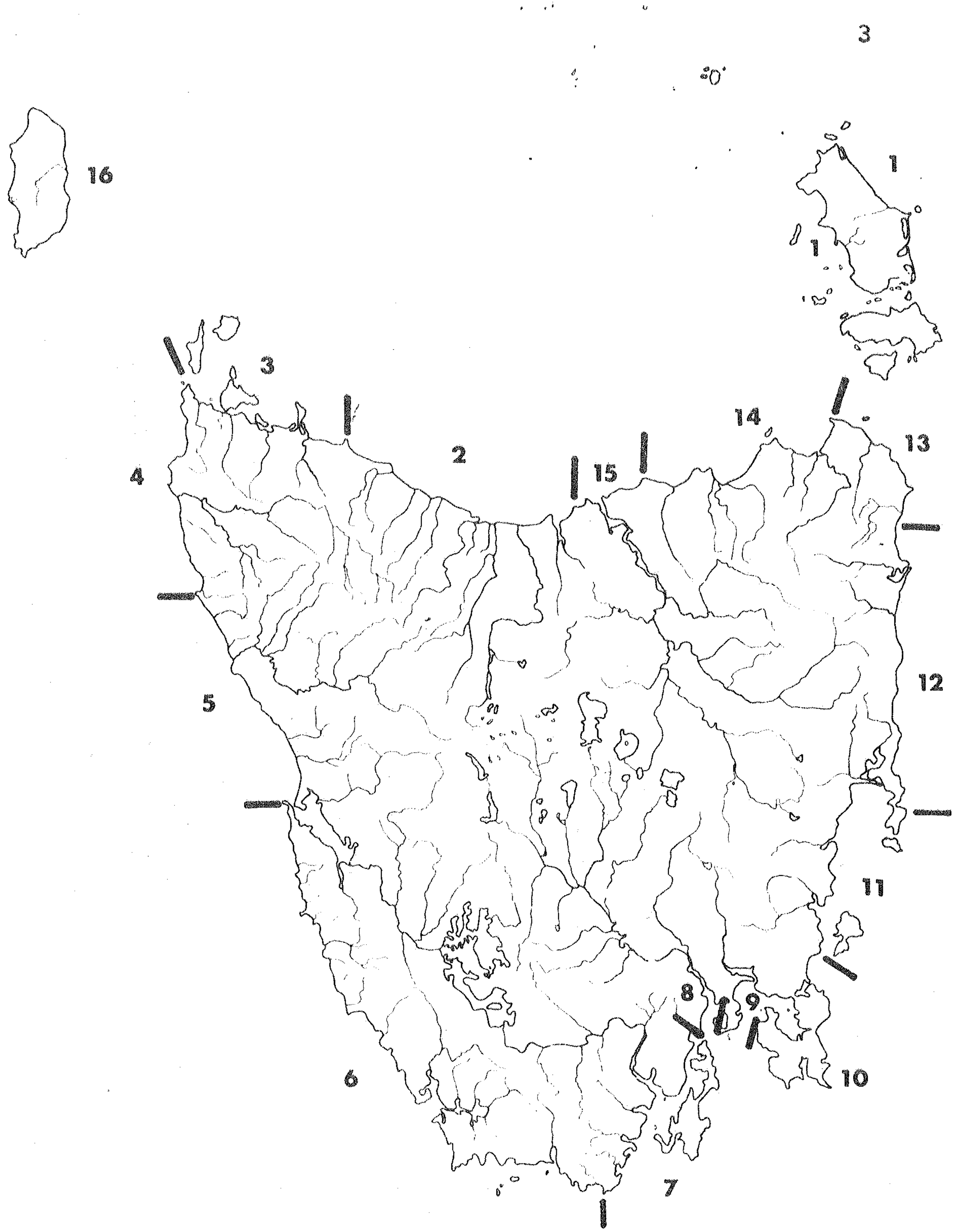
Appendix 4:1 : Copy of Data Sheet.

FISH DISTRIBUTION

FORM X Y	AREA	SITE	DATE
1	2	4	7 12

TEMPERATURE	HABITAT	ESTUARINE INFLUENCE	SUBSTRATE	SEAGRASS	WEED	ROCK	WEED ATTACHMENT	DEPTH	TIME	TIDE	SALINITY	SAMPLE METHOD	QUANTITATIVE STATUS	SURFACE	AREA SWEPT
13	17	19	20			23									32

Code	a	Code	a	Code	a	Code	a	Code	a	Code	a	Code	a	Code	a
001		021		041		061		081		101		121		141	
002		022		042		062		082		102		122		142	
003		023		043		063		083		103		123		143	
004		024		044		064		084		104		124		144	
005		025		045		065		085		105		125		145	
006		026		046		066		086		106		126		146	
007		027		047		067		087		107		127		147	
008		028		048		068		088		108		128		148	
009		029		049		069		089		109		129		149	
010		030		050		070		090		110		130		150	
011		031		051		071		091		111		131		151	
012		032		052		072		092		112		132		152	
013		033		053		073		093		113		133		153	
014		034		054		074		094		114		134		154	
015		035		055		075		095		115		135		155	
016		036		056		076		096		116		136		156	
017		037		057		077		097		117		137		157	
018		038		058		078		098		118		138		158	
019		039		059		079		099		119		139		159	
020		040		060		080		100		120		140		160	



Distribution of the 16 coastal regions referred to in Appendix 4:2.

Codes for minor habitats referred to in Appendix 4:2

Code	Minor habitat
00	Coastal lakes
01	Bar-dammed lagoons (lower)
02	Bar-dammed rivers (lower)
03	Beach-dammed rivers (lower)
04	Bar-dammed lagoons (middle and upper)
06	Beach-dammed rivers (middle and upper)
07	Bar-dammed lagoons (open)
08	Bar-dammed rivers (open)
09	Beach-dammed rivers (open)
11	Open lagoons (bar)
12	Open lagoons (mouth)
13	Open lagoons (mid-lower)
14	Open lagoons (mid)
15	Open lagoons (mid-upper)
16	Open lagoons (pre-riffle)
22	Bay estuaries, deep (mouth)
23	Bay estuaries, deep (mid-lower)
24	Bay estuaries, deep (mid)
25	Bay estuaries, deep (mid-upper)
26	Bay estuaries, deep (pre-riffle)
32	Bay estuaries, flats (mouth)
33	Bay estuaries, flats (mid-lower)
34	Bay estuaries, flats (mid)
35	Bay estuaries, flats (mid-upper)
36	Bay estuaries, flats (pre-riffle)
41	Tidal rivers (bar)
42	Tidal rivers (mouth)
43	Tidal rivers (mid-lower)
44	Tidal rivers (mid)
45	Tidal rivers (mid-upper)
46	Tidal rivers (pre-riffle)
47	Tidal rivers (post-riffle)
51	Tidal creeks (bar)
52	Tidal creeks (mouth)
53	Tidal creeks (mid-lower)
54	Tidal creeks (mid)
56	Tidal creeks (pre-riffle)
57	Tidal creeks (post-riffle)
58	Tidal tributaries (lower)
59	Tidal tributaries (upper)
61	Marginal sheltered beaches (frequent penetration)
62	Marginal semi-exposed beaches (frequent penetration)
65	Marginal sheltered beaches (infrequent penetration)
66	Marginal semi-exposed beaches (infrequent penetration)
67	Marginal exposed beaches (frequent penetration)
71	Sheltered sandy beaches
72	Sheltered muddy beaches
73	Tidal arms
81	Semi-exposed beaches (geological protection)
83	Semi-exposed beaches (biophysical protection)
84	Semi-exposed beaches (wave refraction)
85	Semi-exposed beaches (partial protection)
91	Exposed beaches (continuous swells)
92	Exposed beaches (non-continuous swells)
93	Exposed beaches (wave refraction)

Appendix 4:2 : Sampling sites and their designated minor habitat types from each of the 16 coastal regions of Tasmania.

Coastal Region 1

Site		Minor Habitat
North East River	(147°57'E, 39°45'S)	13
Holloway Point	(147°57'E, 39°44'S)	12
Holloway Point Beach	(147°57'E, 39°44'S)	92
North East River	(147°57'E, 39°45'S)	13
North East River	(147°58'E, 39°46'S)	14
Palana Beach	(147°52'E, 39°46'S	81
Edens Creek	(147°52'E, 39°46'S)	03
Killiecrankie Beach	(147°51'E, 39°50'S)	81
Killiecrankie Creek	(147°51'E, 39°50'S)	03
Castles Rock Point Beach	(147°54'E, 39°59'S)	83
Cave Beach	(147°52'E, 40°01'S)	81
Long Point Beach	(147°57'E, 40°06'S)	81
Pats River	(147°59'E, 40°06'S)	42
Pats River	(148°00'E, 40°06'S)	44
Whitemark Beach	(148°01'E, 40°07'S)	83
Whitemark Beach	(148°01'E, 40°08'S)	83
Nalinga Creek	(148°01'E, 40°08'S)	52
Nalinga Creek	(148°01'E, 40°08'S)	54
Buffalo's Beach	(148°03'E, 40°15'S)	83
Trousers Pt. Beach	(148°02'E, 40°14'S)	83
Trousers Lagoon	(148°02'E, 40°14'S)	00
Big River Cove	(148°06'E, 40°16'S)	83
Badger Corner	(148°11'E, 40°15'S)	71
Samphire River	(148°12'E, 40°13'S)	54
Walters Lagoon Creek	(148°12'E, 40°13'S)	52
Petrification Bay Creek	(148°13'E, 40°13'S)	52
Petrification Bay	(148°14'E, 40°13'S)	72
Yellow Beach	(148°16'E, 40°13'S)	83
White Beach	(148°17'E, 40°13'S)	71
Cameron Inlet	(148°15'E, 40°06'S)	04

Site		Minor Habitat
Cameron Inlet	($148^{\circ}17'E$, $40^{\circ}05'S$)	01
Little Sandy Lagoon	($148^{\circ}15'E$, $40^{\circ}06'S$)	00
Cameron Inlet	($148^{\circ}17'E$, $40^{\circ}05'S$)	04
Sandy Lagoon	($148^{\circ}14'E$, $40^{\circ}06'S$)	00
Patriarch Inlet	($148^{\circ}11'E$, $39^{\circ}56'S$)	12
Patriarch River	($148^{\circ}10'E$, $39^{\circ}56'S$)	15
Kent Island	($145^{\circ}18'E$, $39^{\circ}28'S$)	85
Coastal Region 2		
Port Sorell Beach	($146^{\circ}34'E$, $41^{\circ}10'S$)	22
Panatana Rivulet	($146^{\circ}33'E$, $41^{\circ}10'S$)	58
Squeaking Point Beach	($146^{\circ}34'E$, $41^{\circ}12'S$)	24
Rubicon River	($146^{\circ}34'E$, $41^{\circ}16'S$)	36
South East Arm	($146^{\circ}36'E$, $41^{\circ}14'S$)	35
The Tongue	($146^{\circ}35'E$, $41^{\circ}13'S$)	25
Hawley Beach	($146^{\circ}32'E$, $41^{\circ}09'S$)	66
Pardoe Beach	($146^{\circ}23'E$, $41^{\circ}10'S$)	66
Flour Mill Bay	($146^{\circ}21'E$, $41^{\circ}13'S$)	23
Flour Mill Bay	($146^{\circ}21'E$, $41^{\circ}13'S$)	33
Ballahoo Creek	($146^{\circ}22'E$, $41^{\circ}14'S$)	59
Don River	($146^{\circ}19'E$, $41^{\circ}11'S$)	45
Forth River	($146^{\circ}14'E$, $41^{\circ}10'S$)	42
Forth River	($146^{\circ}15'E$, $41^{\circ}09'S$)	42
Forth River	($146^{\circ}15'E$, $41^{\circ}10'S$)	43
Turner's Beach	($146^{\circ}14'E$, $41^{\circ}10'S$)	62
The Fish Pond	($146^{\circ}12'E$, $41^{\circ}09'S$)	71
Button's Creek	($146^{\circ}11'E$, $41^{\circ}09'S$)	54
Button's Creek Beach	($146^{\circ}11'E$, $41^{\circ}09'S$)	84
Leven Marsh	($146^{\circ}10'E$, $41^{\circ}09'S$)	01
Gawler River	($146^{\circ}09'E$, $41^{\circ}10'S$)	44
Leven River	($146^{\circ}09'E$, $41^{\circ}10'S$)	43
Penguin Beach	($146^{\circ}04'E$, $41^{\circ}07'S$)	84
Preservation Bay	($146^{\circ}03'E$, $41^{\circ}06'S$)	84
Blythe River	($145^{\circ}59'E$, $41^{\circ}05'S$)	42

Site		Minor Habitat
Blythe River	$(145^{\circ}59'E, 41^{\circ}05'S)$	43
Wivenhoe Beach	$(145^{\circ}56'E, 41^{\circ}04'S)$	62
Emu River	$(145^{\circ}56'E, 41^{\circ}04'S)$	42
South Burnie Beach	$(145^{\circ}55'E, 41^{\circ}04'S)$	61
South Burnie Beach	$(145^{\circ}55'E, 41^{\circ}04'S)$	61
Cam River	$(145^{\circ}50'E, 41^{\circ}03'S)$	43
Cam River Beach	$(145^{\circ}50'E, 41^{\circ}02'S)$	62
Seabrook Creek	$(145^{\circ}46'E, 41^{\circ}00'S)$	56
East Wynyard Beach	$(145^{\circ}45'E, 41^{\circ}00'S)$	61
Inglis River	$(145^{\circ}44'E, 40^{\circ}59'S)$	42
Inglis River	$(145^{\circ}44'E, 40^{\circ}59'S)$	43
Boat Harbour Beach	$(145^{\circ}37'E, 40^{\circ}56'S)$	84
Sisters Creek	$(145^{\circ}34'E, 40^{\circ}55'S)$	52
Sisters Creek	$(145^{\circ}34'E, 40^{\circ}55'S)$	53
Sisters Beach	$(145^{\circ}34'E, 40^{\circ}55'S)$	66
Coastal Region 3		
Rocky Cape Beach	$(145^{\circ}30E, 40^{\circ}52'S)$	84
Detention River	$(145^{\circ}27'E, 40^{\circ}53'S)$	43
Pebbly Bay	$(145^{\circ}27'E, 40^{\circ}53'S)$	43
Pebbly Bay	$(145^{\circ}27'E, 40^{\circ}52'S)$	42
Hellyer Beach	$(145^{\circ}26'E, 40^{\circ}52'S)$	66
Crayfish Creek Beach	$(145^{\circ}24'E, 40^{\circ}51'S)$	66
Crayfish Creek	$(145^{\circ}24'E, 40^{\circ}52'S)$	53
Peggs Creek	$(145^{\circ}20'E, 40^{\circ}51'S)$	59
Black River	$(145^{\circ}19'E, 40^{\circ}51'S)$	42
Black River Beach	$(145^{\circ}18'E, 40^{\circ}50'S)$	84
East Inlet	$(145^{\circ}17'E, 40^{\circ}49'S)$	73
East Inlet	$(145^{\circ}17'E, 40^{\circ}48'S)$	73
East Inlet	$(145^{\circ}17'E, 40^{\circ}47'S)$	73
Godfreys Beach	$(145^{\circ}18'E, 40^{\circ}45'S)$	84
Green Hills Beach	$(145^{\circ}16'E, 40^{\circ}45'S)$	71
West Inlet Drain	$(145^{\circ}16'E, 40^{\circ}49'S)$	58

Site		Minor Habitat
West Inlet	($145^{o}16'E, 40^{o}49'S$)	73
Anthony Beach	($145^{o}12'E, 40^{o}48'S$)	84
Anthony Beach	($145^{o}09'E, 40^{o}48'S$)	84
Grays Creek	($145^{o}12'E, 40^{o}50'S$)	56
Duck Bay	($145^{o}08'E, 40^{o}49'S$)	23
Eagle Point	($145^{o}07'E, 40^{o}48'S$)	22
Kingston Point	($145^{o}07'E, 40^{o}48'S$)	22
Sampsons Point	($145^{o}08'E, 40^{o}50'S$)	24
Duck River	($145^{o}08'E, 40^{o}50'S$)	24
Acton Bay	($145^{o}02'E, 40^{o}47'S$)	52
Acton Creek	($145^{o}02'E, 40^{o}47'S$)	53
Stony Point	($144^{o}59'E, 40^{o}45'S$)	65
Stony Point	($144^{o}59'E, 40^{o}45'S$)	65
Robbins Island	($144^{o}58'E, 40^{o}43'S$)	65
Montagu Beach	($144^{o}58'E, 40^{o}45'S$)	65
Robbins Passage	($144^{o}57'E, 40^{o}45'S$)	61
Robbins Passage	($144^{o}56'E, 40^{o}45'S$)	32
Welcome Inlet	($144^{o}47'E, 40^{o}42'S$)	65
Shoal Inlet	($144^{o}45'E, 40^{o}41'S$)	71
Murkay Beach	($144^{o}44'E, 40^{o}40'S$)	71
Middle Beach	($144^{o}44'E, 40^{o}39'S$)	71
Woolnorth Point	($144^{o}44'E, 40^{o}38'S$)	81
Woolnorth Point	($144^{o}43'E, 40^{o}39'S$)	81
Coastal Region 4		
Three Mile Sand	($144^{o}41'E, 40^{o}54'S$)	91
Arthur River Bridge	($144^{o}40'E, 41^{o}03'S$)	43
Arthur River	($144^{o}40'E, 41^{o}03'S$)	42
Arthur River	($144^{o}40'E, 41^{o}03'S$)	42
Arthur River	($144^{o}40'E, 41^{o}03'S$)	42
Nelson River	($144^{o}41'E, 41^{o}08'S$)	03
Nelson River	($144^{o}41'E, 41^{o}08'S$)	06
Rebecca Lagoon	($144^{o}42'E, 41^{o}11'S$)	00
Temma Harbour	($144^{o}41'E, 41^{o}14'S$)	81
Temma Harbour	($144^{o}41'E, 41^{o}14'S$)	81
West Point	($144^{o}37'E, 40^{o}56'S$)	81

Coastal Region 5

Site		Minor Habitat
Braddon Point	(145°13'E, 42°13'S)	22
Braddon Point	(145°14'E, 42°13'S)	22
Wellington Head Beach	(145°13'E, 42°14'S)	22
Back Channel Beach	(145°14'E, 42°14'S)	22
Channel Bay	(145°14'E, 42°15'S)	23
Mill Bay	(145°19'E, 42°9'S)	23
West Strahan Beach	(145°19'E, 42°9'S)	23
West Strahan Beach	(145°19'E, 42°9'S)	23
West Strahan Creek	(145°19'E, 42°9'S)	58
Lettes Bay	(145°22'E, 42°10'S)	23
King River	(145°21'E, 42°12'S)	23
Sofia Point Beach	(145°22'E, 42°15'S)	23
Gould Point Beach	(145°29'E, 42°22'S)	23
Liberty Point Beach	(145°19'E, 42°18'S)	24
Big Pebbly Beach	(145°31'E, 42°25'S)	25
Pieman River	(144°55'E, 41°40'S)	41
Violet Rivulet	(144°55'E, 41°41'S)	52
Pieman River	(144°55'E, 41°40'S)	42
Pieman River	(144°56'E, 41°40'S)	42
Ferry Point	(144°56'E, 41°40'S)	43
Pieman River	(144°56'E, 41°40'S)	43

Coastal Region 6

Davey River	(145°55'E, 43°13'S)	22
Bond Bay Beach	(145°54'E, 43°15'S)	62
Bond Bay Beach	(145°54'E, 43°16'S)	62
Garden Point Beach	(145°55'E, 43°16'S)	62
Garden Point	(145°54'E, 43°16'S)	73
Kelly Basin	(145°52'E, 43°17'S)	73
Kelly Basin	(145°52'E, 43°17'S)	73
Kelly Basin	(145°52'E, 43°16'S)	61
Quail Flat Creek	(145°52'E, 43°16'S)	52

Site		Minor Habitat
Cockburn Cove	(145°52'E, 43°16'S)	73
Melaleuca Lagoon	(146°09'E, 43°25'S)	26
Celery Top Beach	(146°09'E, 43°23'S)	26
Beattie Creek Beach	(146°07'E, 43°22'S)	26
Melaleuca Inlet	(146°07'E, 43°23'S)	26
Platypus Point Beach	(146°07'E, 43°21'S)	25
Balmoral Beach	(146°04'E, 43°21'S)	24
Schooner Cove	(146°00'E, 43°21'S)	22

Coastal Region 7

Fords Green Creek	(146°54'E, 43°35'S)	09
Cockle Creek	(146°54'E, 43°35'S)	52
Cockle Creek Beach	(146°54'E, 43°35'S)	85
Cockle Creek	(146°53'E, 43°35'S)	54
Ramsgate Creek	(146°53'E, 43°35'S)	52
Ramsgate Beach	(146°53'E, 43°35'S)	84
Stonybight Beach	(146°53'E, 43°34'S)	72
Driscolls Creek	(146°53'E, 43°33'S)	52
Driscolls Creek Beach	(146°53'E, 43°33'S)	84
D'Entrecasteaux River	(146°54'E, 43°31'S)	22
Catamaran River	(146°53'E, 43°33'S)	43
Southport Lagoon	(146°58'E, 43°29'S)	73
The Deep Hole	(146°58'E, 43°27'S)	61
Southport Narrows	(146°58'E, 43°27'S)	22
Kingfish Beach	(146°58'E, 43°27'S)	62
Kingfish Beach	(146°58'E, 43°26'S)	62
Settlement Creek	(146°58'E, 43°26'S)	53
East Kingfish Beach	(146°59'E, 43°26'S)	62
West Dover Beach	(147°01'E, 43°19'S)	61
Dover Rivulet	(147°01'E, 43°19'S)	02
Dover Beach	(147°02'E, 43°19'S)	65
Knobbys Point	(147°02'E, 43°19'S)	65
Kents Beach	(147°03'E, 43°19'S)	65
Roaring Bay	(147°05'E, 43°18'S)	66
Surveyors Bay	(147°05'E, 43°17'S)	62
Brooks Bay	(147°02'E, 43°14'S)	22

Site		Minor Habitat
Huon River	(147°02'E, 43°04'S)	24
Huon River	(147°00'E, 43°06'S)	24
Nicholls Rivulet	(147°05'E, 43°10'S)	61
Cygnet Bay	(147°05'E, 43°10'S)	61
Supplices Creek	(147°05'E, 43°10'S)	54
Pickup Beach	(147°09'E, 43°17'S)	62
Esperance Narrows	(146°59'E, 43°20'S)	33
Surges Bay	(146°59'E, 43°13'S)	22
Gordon Beach	(147°14'E, 43°16'S)	65
Middleton Beach	(147°15'E, 43°14'S)	65
Trial Bay	(147°15'E, 43°08'S)	65
Kettering Bay	(147°15'E, 43°07'S)	65
Oyster Cove	(147°16'E, 43°06'S)	65
Coningham Beach	(147°16'E, 43°05'S)	65
Snug Bay Creek	(147°15'E, 43°04'S)	54
Snug Bay	(147°16'E, 43°04'S)	65
Snug Beach	(147°16'E, 43°04'S)	65
Snug River	(147°16'E, 43°04'S)	52
Coffee Creek Bay	(147°17'E, 43°01'S)	65
Tinderbox Bay	(147°20'E, 43°04'S)	65
Alexander Bay	(147°19'E, 43°08'S)	65
Little Fancy Bay	(147°21'E, 43°13'S)	65
Cloudy Bay Lagoon	(147°12'E, 43°26'S)	13
Dennes Point Beach	(147°21'E, 43°04'S)	65
Nebraska Beach	(147°20'E, 43°05'S)	65
Stiffys Creek	(147°20'E, 43°05'S)	03
Bull Bay	(147°22'E, 43°05'S)	66
The Neck Beach	(147°21'E, 43°17'S)	92
Resolution Creek	(147°20'E, 43°21'S)	06
Captain Cook Creek	(147°20'E, 43°22'S)	53
Captain Cook Creek	(147°20'E, 43°22'S)	51
Cloudy Bay Lagoon	(147°12'E, 43°26'S)	12
Cloudy Bay Lagoon	(147°13'E, 43°26'S)	14
Mickeys Bay	(147°11'E, 43°26'S)	71
Lunawanna Creek	(147°13'E, 43°22'S)	51
Alonah	(147°14'E, 43°19'S)	65

Site		Minor Habitat
Lutregala Creek	$(147^{o}18'E, 43^{o}17'S)$	51
Isthmus Bay	$(147^{o}20'E, 43^{o}16'S)$	65

Coastal Region 8

Blackman's Bay Beach	$(147^{o}20'E, 43^{o}01'S)$	66
Kingston Beach	$(147^{o}20'E, 42^{o}59'S)$	66
Browns River	$(147^{o}20'E, 42^{o}59'S)$	53
Browns River	$(147^{o}20'E, 42^{o}59'S)$	51
Taroona Beach	$(147^{o}21'E, 42^{o}57'S)$	66
Little Sandy Bay	$(147^{o}21'E, 42^{o}55'S)$	22
Sandy Bay Beach	$(147^{o}21'E, 42^{o}55'S)$	22
Wrest Point Beach	$(147^{o}20'E, 42^{o}54'S)$	32
Yacht Club Beach	$(147^{o}20'E, 42^{o}54'S)$	32
Cornelian Bay	$(147^{o}19'E, 42^{o}51'S)$	23
Lowestoff Bay	$(147^{o}15'E, 42^{o}49'S)$	23
Beedhams Bay	$(147^{o}16'E, 42^{o}47'S)$	24
Risdon Creek	$(147^{o}19'E, 42^{o}49'S)$	59
Lindisfarne Bay	$(147^{o}21'E, 42^{o}51'S)$	23
Howrah Beach	$(147^{o}24'E, 42^{o}53'S)$	22
Rokeby Beach	$(147^{o}26'E, 42^{o}55'S)$	65
Ralph's Bay	$(147^{o}26'E, 43^{o}02'S)$	65
Oppossum Bay	$(147^{o}24'E, 42^{o}59'S)$	66
Half Moon Bay	$(147^{o}25'E, 43^{o}02'S$	66
Lauderdale Canal	$(147^{o}29'E, 42^{o}55'S)$	61

Coastal Region 9

Pipe Clay Lagoon	$(147^{o}32'E, 42^{o}59'S)$	73
Clifton Beach	$(147^{o}32'E, 42^{o}59'S)$	93
Pipe Clay Lagoon	$(147^{o}32'E, 42^{o}58'S)$	73
Lauderdale Beach	$(147^{o}30'E, 42^{o}54'S)$	84
Seven Mile Beach Creek	$(147^{o}30'E, 42^{o}52'S)$	03
Seven Mile Beach	$(147^{o}30'E, 42^{o}52'S)$	84
Pittwater	$(147^{o}31'E, 42^{o}49'S)$	14
Penna Beach	$(147^{o}31'E, 42^{o}47'S)$	15

Site		Minor Habitat
Frogmore Creek	($147^{o}32'E$, $42^{o}47'S$)	59
Orielton Rivulet	($147^{o}32'E$, $42^{o}47'S$)	58
Sorell Rivulet	($147^{o}34'E$, $42^{o}48'S$)	58
Iron Creek Bay	($147^{o}35'E$, $42^{o}48'S$)	15
Iron Creek	($147^{o}35'E$, $42^{o}48'S$)	59
Jones Bay	($147^{o}36'E$, $42^{o}50'S$)	13
China Creek	($147^{o}37'E$, $42^{o}50'S$)	59
Okines Beach	($147^{o}37'E$, $42^{o}51'S$)	12
Tiger Head Bay	($147^{o}36'E$, $42^{o}52'S$)	61
Red Ochre Beach	($147^{o}36'E$, $42^{o}52'S$)	65
Carlton Beach	($147^{o}38'E$, $42^{o}53'S$)	67
Carlton River	($147^{o}38'E$, $42^{o}53'S$)	22
Carlton River	($147^{o}39'E$, $42^{o}53'S$)	33
Carlton River	($147^{o}39'E$, $42^{o}53'S$)	23
Carlton River	($147^{o}40'E$, $42^{o}52'S$)	24
Primrose Beach	($147^{o}39'E$, $42^{o}53'S$)	92
Chaseys Creek	($147^{o}40'E$, $42^{o}52'S$)	59
Carlton River	($147^{o}41'E$, $42^{o}52'S$)	25
Conelly's Bay	($147^{o}43'E$, $42^{o}54'S$)	84
Stroud's Point	($147^{o}47'E$, $42^{o}54'S$)	72
Dunalley Beach	($147^{o}49'E$, $42^{o}55'S$)	71
King George Sound	($147^{o}51'E$, $42^{o}56'S$)	72
Eaglehawk Bay	($147^{o}55'E$, $43^{o}01'S$)	72
Newman's Creek	($147^{o}50'E$, $43^{o}04'S$)	42
Seven Mile Beach	($147^{o}35'E$, $42^{o}50'S$)	84
Five Mile Beach	($147^{o}36'E$, $42^{o}50'S$)	23
Newman's Creek	($147^{o}51'E$, $43^{o}04'S$)	43
Cascades Bay	($147^{o}49'E$, $43^{o}03'S$)	72
Saltwater River	($147^{o}44'E$, $43^{o}02'S$)	43
Sloping Main	($147^{o}40'E$, $43^{o}00'S$)	71

Coastal Region 10

Site		Minor Habitat
Roaring Beach Lagoon	(147°40'E, 43°05'S)	03
Roaring Beach Bay	(147°40'E, 43°05'S)	91
Parsons Bay	(147°44'E, 43°06'S)	61
White Beach	(147°44'E, 43°07'S)	84
Parsons Bay Creek	(147°44'E, 43°07'S)	51
White Beach	(147°44'E, 43°07'S)	84
White Beach Lagoon	(147°44'E, 43°07'S)	01
Cripps Creek	(147°43'E, 43°07'S)	43
Cripps Creek Beach	(147°43'E, 43°08'S)	71
Wades Corner	(147°43'E, 43°08'S)	71
Dog Bark Creek	(147°51'E, 43°11'S)	03
Safety Cove	(147°51'E, 43°11'S)	84
Safety Cove	(147°51'E, 43°11'S)	93
Safety Cove Creek	(147°51'E, 43°11'S)	09
Point Puer Beach	(147°52'E, 43°09'S)	71
Briar Paddock Beach	(147°51'E, 43°11'S)	72
Carnarvon Bay	(147°51'E, 43°10'S)	71
Carnarvon Bay	(147°51'E, 43°09'S)	71
Stewarts Bay	(147°51'E, 43°08'S)	61
Stewarts Inlet	(147°51'E, 43°08'S)	61
Long Bay Creek	(147°52'E, 43°06'S)	51
Stewarts Bay	(147°51'E, 43°08'S)	71
Fortesque Bay	(147°58'E, 43°08'S)	84
Fortesque Lagoon	(147°57'E, 43°08'S)	01
Pirates Bay	(147°56'E, 43°02'S)	84
Blowhole Creek	(147°56'E, 43°02'S)	52
Pirates Bay	(147°55'E, 43°02'S)	92
Marion Narrows	(147°52'E, 42°51'S)	73
Little Boomer Bay	(147°51'E, 42°51'S)	73
Blackman Bay	(147°52'E, 42°50'S)	73
Bream Creek	(147°52'E, 42°49'S)	01

Coastal Region 11

Site		Minor Habitat
Earlham Lagoon	($147^{o}58$'E, $42^{o}39$'S)	13
Earlham Lagoon	($147^{o}58$'E, $42^{o}39$'S)	12
Sandspit Point	($147^{o}58$'E, $42^{o}39$'S)	92
Carrickfergus Bay	($147^{o}56$'E, $42^{o}38$'S)	81
Two Mile Creek	($147^{o}55$'E, $42^{o}35$'S)	03
Prosser River	($147^{o}53$'E, $42^{o}34$'S)	13
Prosser River	($147^{o}53$'E, $42^{o}34$'S)	13
Raspins Beach	($147^{o}53$'E, $42^{o}33$'S)	62
Spring Bay	($147^{o}55$'E, $42^{o}32$'S)	65
Maclaines Inlet	($147^{o}55$'E, $42^{o}30$'S)	23
Little Swanport	($147^{o}59$'E, $42^{o}19$'S)	33
Limekiln Point	($147^{o}59$'E, $42^{o}19$'S)	23
Ravensdale Rivulet	($147^{o}56$'E, $42^{o}21$'S)	59
Watchhouse Bay	($147^{o}56$'E, $42^{o}21$'S)	36
Lisdillon Rivulet	($148^{o}00$'E, $42^{o}18$'S)	07
Lisdillon Lagoon	($148^{o}00$'E, $42^{o}17$'S)	07
Buxton Beach	($148^{o}01$'E, $42^{o}16$'S)	84
Buxton River	($148^{o}01$'E, $42^{o}16$'S)	22
Buxton River	($148^{o}01$'E, $42^{o}16$'S)	23
Brickfield Beach	($148^{o}01$'E, $42^{o}14$'S)	84
Mayfield Beach	($148^{o}01$'E, $42^{o}15$'S)	71
Kelvedon Lagoon	($148^{o}03$'E, $42^{o}12$'S)	01
Saltwater Creek	($148^{o}04$'E, $42^{o}08$'S)	02
Swansea Beach	($148^{o}05$'E, $42^{o}08$'S)	84
Meredith River	($148^{o}04$'E, $42^{o}07$'S)	09
Nine Mile Beach	($148^{o}04$'E, $42^{o}07$'S)	84
Meredith River	($148^{o}04$'E, $42^{o}07$'S)	09
Nine Mile Beach	($148^{o}09$'E, $42^{o}06$'S)	92
Point Bagot	($148^{o}14$'E, $42^{o}06$'S)	12
Great Swanport	($148^{o}14$'E, $42^{o}06$'S)	12
Point Bagot	($148^{o}14$'E, $42^{o}06$'S)	12
Swanwick Bay	($148^{o}14$'E, $42^{o}06$'S)	12

Site		Minor Habitat
Swanwick Creek	($148^{o}14'E, 42^{o}05'S$)	58
Great Swanport	($148^{o}14'E, 42^{o}05'S$)	13
Great Swanport	($148^{o}14'E, 42^{o}05'S$)	13
Point Meredith	($148^{o}13'E, 42^{o}05'S$)	13
The Yellow Sandbanks	($148^{o}10'E, 42^{o}05'S$)	13
King Bay	($148^{o}09'E, 42^{o}04'S$)	14
Swan River	($148^{o}06'E, 42^{o}05'S$)	15
Barney Wards Bay	($148^{o}10'E, 42^{o}03'S$)	14
Little Bay	($148^{o}09'E, 42^{o}03'S$)	15
Moulting Lagoon	($148^{o}14'E, 42^{o}01'S$)	15
Moulting Lagoon	($148^{o}18'E, 42^{o}08'S$)	16
Chinamans Bay	($148^{o}02'E, 42^{o}39'S$)	71
Chinamans Bay Creek	($148^{o}02'E, 42^{o}39'S$)	14
Bloodstone Beach	($148^{o}02'E, 42^{o}39'S$)	84
Point Lesueur Beach	($148^{o}01'E, 42^{o}40'S$)	84
Riedle Bay	($148^{o}04'E, 42^{o}41'S$)	92
Chinamans Bay	($148^{o}02'E, 42^{o}39'S$)	71
Chinamans Bay Creek	($148^{o}02'E, 42^{o}40'S$)	11
Chinamans Bay Creek	($148^{o}02'E, 42^{o}40'S$)	13
Moulting Lagoon	($148^{o}14'E, 42^{o}00'S$)	16

Coastal Region 12

Waubs Bay	($148^{o}18'E, 41^{o}52'S$)	81
Redbill Beach	($148^{o}17'E, 41^{o}52'S$)	81
Old Mines Lagoon	($148^{o}16'E, 41^{o}50'S$)	04
Denison Rivulet	($148^{o}16'E, 41^{o}49'S$)	02 + 08
Douglas River	($148^{o}17'E, 41^{o}47'S$)	08
Douglas River	($148^{o}17'E, 41^{o}47'S$)	08
Templestowe Lagoon	($148^{o}17'E, 41^{o}44'S$)	66
Templestowe Lagoon	($148^{o}17'E, 41^{o}44'S$)	07
Templestowe Lagoon	($148^{o}16'E, 41^{o}43'S$)	04
Templestowe Lagoon	($148^{o}17'E, 41^{o}44'S$)	07
Four Mile Creek	($148^{o}17'E, 41^{o}33'S$)	23
Four Mile Creek Beach	($148^{o}17'E, 41^{o}33'S$)	67
Henderson Lagoon	($148^{o}16'E, 41^{o}30'S$)	01 + 07

Site		Minor Habitat
Henderson Lagoon	(148°16'E, 41°30'S)	07
Henderson Lagoon	(148°15'E, 41°29'S)	07
Scamander River	(148°16'E, 41°28'S)	23
Scamander River	(148°15'E, 41°28'S)	23
Doyles Mudflat	(148°14'E, 41°28'S)	34
Wrinklers Lagoon	(148°16'E, 41°27'S)	01
Wrinklers Lagoon	(148°16'E, 41°27'S)	04
Dianas Beach	(148°17'E, 41°24'S)	92
Dianas Basin	(148°17'E, 41°22'S)	07 + 01
Arm Creek	(148°17'E, 41°23'S)	59
Dianas Basin	(148°17'E, 41°23'S)	07 + 04
Stieglitz Beach	(148°18'E, 41°19'S)	14
Stockyard Flats	(148°18'E, 41°19'S)	14
Georges Bay	(148°19'E, 41°18'S)	13
Pelican Point	(148°19'E, 41°17'S)	13
O'Connor's Beach	(148°16'E, 41°20'S)	15
Boggy Creek Beach	(148°16'E, 41°20'S)	15
Jasons Gates	(148°15'E, 41°19'S)	16
Medeas Cove	(148°14'E, 41°20'S)	16
Bayview Beach	(148°16'E, 41°18'S)	16
Wilsons Bay	(148°17'E, 41°18'S)	16
Bayview Beach	(148°16'E, 41°18'S)	16
Grants Lagoon	(148°18'E, 41°15'S)	07
Binalong Bay	(148°18'E, 41°15'S)	66
Sloop Lagoon	(148°15'E, 41°12'S)	07
Big Lagoon	(148°16'E, 41°11'S)	07
Big Lagoon	(148°14'E, 41°11'S)	07

Coastal Region 13

Ansons Bay	(148°17'E, 41°04'S)	12
Ansons Bay	(148°17'E, 41°04'S)	13
Ansons Bay	(148°17'E, 41°04'S)	13
Ansons Bay	(148°17'E, 41°04'S)	13

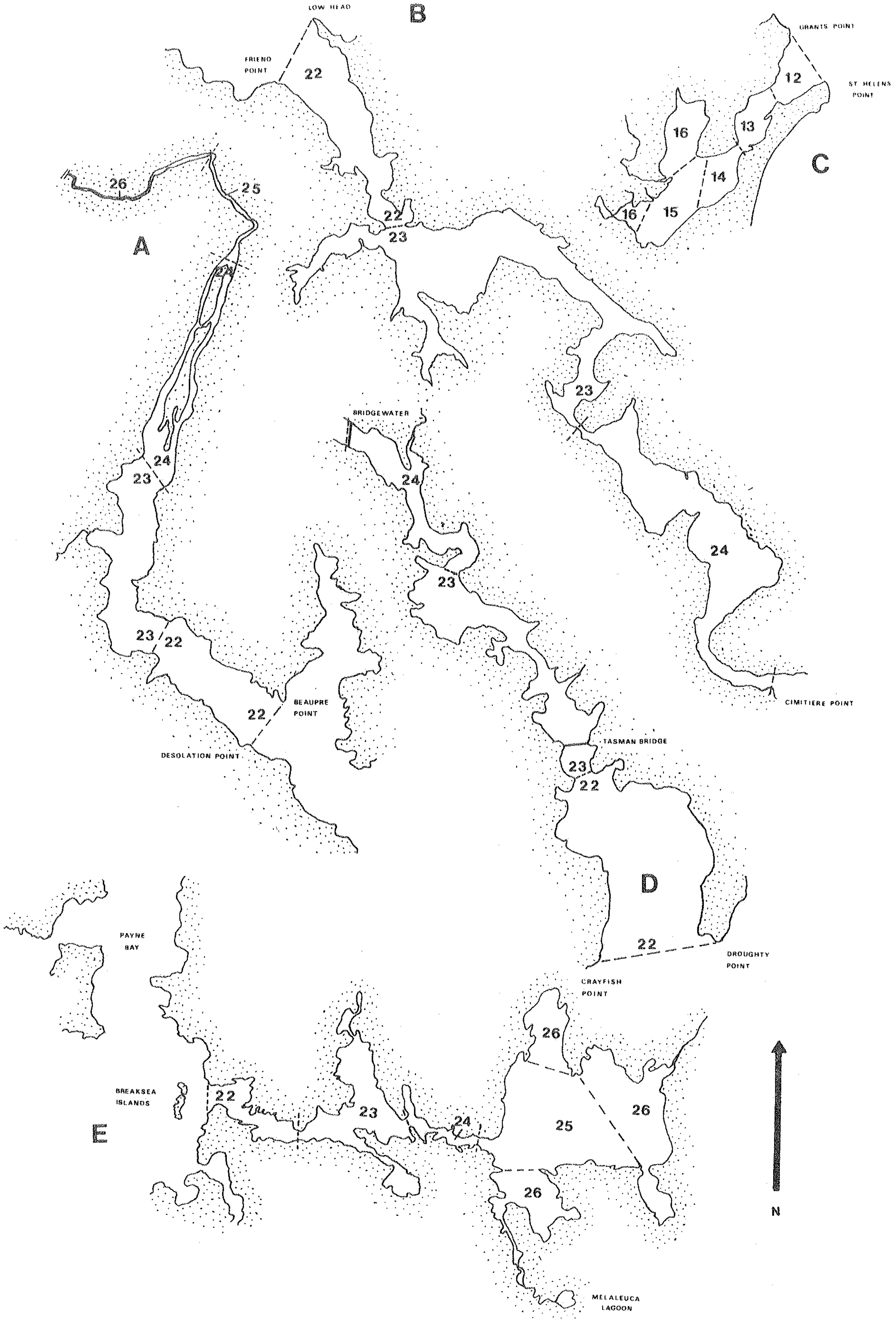
Site		Minor Habitat
Ansons Bay	(148°17'E, 41°04'S)	13
Ansons Bay	(148°17'E, 41°03'S)	13
Ansons Bay	(148°17'E, 41°03'S)	13
Rocky Point Beach	(148°15'E, 41°03'S)	15
Rocky Point Beach	(148°15'E, 41°03'S)	15
North Picnic Corner Beach	(148°19'E, 40°59'S)	92
Groves Creek	(148°18'E, 40°58'S)	42
Musselroe Bay	(148°10'E, 40°50'S)	13
Musselroe Bay	(148°09'E, 40°50'S)	13
Little Musselroe Bay	(148°02'E, 40°46'S)	13
Little Musselroe Bay	(148°02'E, 40°46'S)	13
Little Musselroe Beach	(148°02'E, 40°46'S)	92
Semaphore Hill Beach	(147°57'E, 40°45'S)	71
Semaphore Hill Lagoon	(147°58'E, 40°45'S)	00
Fosters Inlet	(147°57'E, 40°45'S)	81
Steels Creek Cove	(148°15'E, 41°03'S)	14

Coastal Region 14

Ringarooma River	(147°53'E, 40°53'S)	08
Ringarooma River	(147°53'E, 40°53'S)	08
Tomahawk Beach	(147°46'E, 40°52'S)	84
Tomahawk River	(147°46'E, 40°52'S)	42
West Tomahawk Beach	(147°42'E, 40°51'S)	84
Waterhouse Point Beach	(147°40'E, 40°50'S)	84
Brewers Creek	(147°25'E, 41°01'S)	52
Hurst Creek	(147°25'E, 41°01'S)	14
Brid River	(147°24'E, 41°01'S)	13
Bridport Beach	(147°23'E, 41°00'S)	66
Bridport Beach	(147°23'E, 41°00'S)	66
Bridport Beach	(147°23'E, 40°59'S)	66
Adams Beach	(147°23'E, 40°59'S)	66
Little Forester River	(147°21'E, 40°59'S)	42
Lades Beach	(147°21'E, 40°58'S)	66
Lades Beach	(147°21'E, 40°57'S)	66

Site		Minor Habitat
Little Pipers River	$(147^{o}12'E, 41^{o}00'S)$	46
Little Pipers River	$(147^{o}12'E, 41^{o}00'S)$	41
Pipers River	$(147^{o}09'E, 41^{o}01'S)$	43
Pipers River	$(147^{o}09'E, 41^{o}01'S)$	44
Curries River	$(146^{o}57'E, 41^{o}02'S)$	43
Curries River Beach	$(146^{o}56'E, 41^{o}02'S)$	84
Coastal Region 15		
Paper Beach	$(146^{o}57'E, 41^{o}15'S)$	34
Swan Point	$(146^{o}58'E, 41^{o}15'S)$	34
Sandy Beach	$(146^{o}49'E, 41^{o}09'S)$	33
Middle Arm	$(146^{o}50'E, 41^{o}04'S)$	33
York Cove	$(146^{o}49'E, 41^{o}07'S)$	33
York Creek	$(146^{o}49'E, 41^{o}07'S)$	58
Kelso Beach	$(146^{o}47'E, 41^{o}06'S)$	33
Kelso Beach	$(146^{o}47'E, 41^{o}06'S)$	33
Kelso Beach	$(146^{o}47'E, 41^{o}06'S)$	33
Kelso Bay	$(146^{o}47'E, 41^{o}07'S)$	33
Lagoon Bay	$(146^{o}48'E, 41^{o}04'S)$	32
Pilots Bay	$(146^{o}47'E, 41^{o}04'S)$	32
Greens Beach	$(146^{o}45'E, 41^{o}05'S)$	62
Badger Creek	$(146^{o}41'E, 41^{o}06'S)$	03
Badger Beach	$(146^{o}40'E, 41^{o}06'S)$	92
East Beach	$(146^{o}48'E, 41^{o}04'S)$	81
Coastal Region 16		
Sea Elephant River	$(144^{o}07'E, 39^{o}49'S)$	13
Sea Elephant River	$(144^{o}07'E, 39^{o}49'S)$	13
Sea Elephant River	$(144^{o}07'E, 39^{o}49'S)$	13
Lake Martha Lavinia	$(144^{o}04'E, 39^{o}39'S)$	00
Lake Wickham	$(143^{o}58'E, 39^{o}36'S)$	00
Victoria Cove	$(143^{o}56'E, 39^{o}36'S)$	92
Yellow Rock Beach	$(143^{o}54'E, 39^{o}42'S)$	92

Site		Minor Habitat
Little Cask Lake	($143^{\circ}58$'E, $39^{\circ}37$'S)	00
Lake Flannigan	($143^{\circ}58$'E, $39^{\circ}37$'S)	00
Lake Flannigan	($143^{\circ}58$'E, $39^{\circ}38$'S)	00
Yellow Rock River	($143^{\circ}54$'E, $39^{\circ}42$'S)	43
Yellow Rock River	($143^{\circ}54$'E, $39^{\circ}42$'S)	41
Yellow Rock River	($143^{\circ}53$'E, $39^{\circ}42$'S)	46
Quarantine Bay	($143^{\circ}52$'E, $39^{\circ}43$'S)	92
Currie Harbour	($143^{\circ}51$'E, $39^{\circ}56$'S)	71
Currie Beach	($143^{\circ}51$'E, $39^{\circ}56$'S)	71
Camp Creek	($143^{\circ}51$'E, $39^{\circ}56$'S)	51
Currie Beach	($143^{\circ}51$'E, $39^{\circ}56$'S)	71
Pass River	($143^{\circ}52$'E, $39^{\circ}48$'S)	52
Badger Box Beach	($143^{\circ}52$'E, $39^{\circ}58$'S)	92
Badger Box Creek	($143^{\circ}52$'E, $39^{\circ}58$'S)	57
Dead Sea	($143^{\circ}57$'E, $39^{\circ}58$'S)	00
Swan Lagoon	($143^{\circ}57$'E, $39^{\circ}58$'S)	00
Ettrick River	($143^{\circ}53$'E, $40^{\circ}00$'S)	47
Ettrick Bay	($143^{\circ}53$'E, $40^{\circ}00$'S)	62
Little Pearshape Lagoon	($143^{\circ}55$'E, $40^{\circ}05$'S)	00
Surprise Bay	($143^{\circ}54$'E, $40^{\circ}08$'S)	81
Surprise Bay	($143^{\circ}54$'E, $40^{\circ}08$'S)	81
Colliers Beach	($144^{\circ}00$'E, $40^{\circ}06$'S)	92
Broken Arm River	($144^{\circ}02$'E, $40^{\circ}05$'S)	09
Broken Arm Beach	($144^{\circ}02$'E, $40^{\circ}05$'S)	92
Little Grassy Beach	($144^{\circ}03$'E, $40^{\circ}04$'S)	92
Little Grassy Creek	($144^{\circ}03$'E, $40^{\circ}04$'S)	09 + 03
Grassy Harbour	($144^{\circ}04$'E, $40^{\circ}04$'S)	71
City of Melbourne Bay	($144^{\circ}07$'E, $40^{\circ}01$'S)	81
Yarra Creek	($144^{\circ}07$'E, $40^{\circ}01$'S)	52
Fraser River	($144^{\circ}07$'E, $39^{\circ}55$'S)	41
Fraser Beach	(144° 07'E, $39^{\circ}52$'S)	92



Appendix 4:3. Entrances and upstream boundaries for estuaries of: (A) Huon River; (B) Tamar River; (C) Georges Bay; (D) Derwent River; and (E) Bathurst Harbour. Positions follow codes in Appendix 4:2. North is designated by N.

Appendix 4:4 : Distribution of species at each major habitat. (A) closed estuaries, (B) open estuaries (lower), (C) open estuaries (upper), (D) sheltered beaches, (E) semi-exposed beaches, (F) exposed beaches.

Species	A	B	C	D	E	F	Total	G statistics
Geotria australis	0	1	0	0	0	0	1	1.91
Squalus acanthias	0	0	0	0	1	0	1	3.59
Narcine tasmaniensis	0	0	0	0	1	0	1	3.59
Raja lemprieri	0	0	0	0	1	0	1	3.59
Raja whitleyi	0	0	0	0	1	0	1	3.59
Urolophus cruciatus	0	2	0	1	1	0	4	2.50
Urolophus paucimaculatus	0	1	0	0	1	0	2	2.73
Myliobatis australis	0	1	0	0	0	0	1	1.91
Spratelloides robustus	0	5	1	5	4	0	15	6.82
Engraulis australis	0	3	4	3	1	0	11	6.29
Anguilla reinhardtii	0	1	1	0	0	0	2	2.94
Anguilla australis	5	13	16	0	0	0	34	44.66
Muraenichthys breviceps	0	0	0	1	0	0	1	3.40
Salmo trutta	0	1	1	0	0	0	2	2.94
Retropinna tasmanica	1	24	17	1	0	0	43	46.43
Prototroctes maraena	0	7	2	0	0	0	9	11.52
Lovettia sealii	0	10	5	4	0	0	19	13.21
Galaxias truttaceus	4	14	3	10	0	0	31	17.83
Galaxias maculatus	12	70	37	2	1	0	122	111.43
Pseudophycis bachus	0	5	0	5	1	0	11	9.68
Genypterus sp.	0	0	2	0	0	0	2	7.62
Brachionichthys hirsutus	0	1	0	0	0	0	1	1.91
Hyporhamphus melanochir	0	11	3	16	8	1	39	18.42
Atherinosoma microstoma	35	111	67	50	2	0	265	156.64
Atherinosoma presbyteroides	3	99	36	115	45	1	299	170.53
Atherinason esox	0	1	0	39	3	0	43	123.36
Atherinason sp.	0	7	0	14	2	0	23	28.72
Atherinason hepsetoides	0	3	0	2	3	0	8	6.02
Cyttus australis	0	0	0	0	1	0	1	3.59
Hypselognathus rostratus	0	0	0	1	0	0	1	3.40
Lissocampus runa	0	0	0	3	0	0	3	10.25
Urocampus carinirostris	3	2	10	0	0	0	15	32.06
Leptonotus costatus	0	0	1	0	0	0	1	3.80
Leptonotus semistriatus	1	2	0	10	3	0	16	20.86
Leptoichthys fistularius	0	0	0	1	0	0	1	3.40
Syngnathus tuckeri	0	0	0	3	9	1	13	28.91
Syngnathus curtirostris	0	1	0	1	1	0	3	2.31
Syngnathus phillipi	0	7	11	9	0	0	27	28.11
Syngnathus poecilolaemus	0	0	1	0	1	0	2	4.62
Stigmatopora nigra	0	36	23	18	0	0	77	58.36
Stigmatopora argus	0	17	14	26	4	0	61	40.45
Hippocampus abdominalis	0	8	2	1	0	0	11	9.66
Hippocampus breviceps	0	0	0	5	2	0	7	15.93
Alabes parvulus	0	0	0	1	0	0	1	3.40
Alabes dorsalis	0	1	0	0	0	0	1	1.91
Gymnapistes marmoratus	2	29	26	40	1	0	98	76.42
Scorpaena ergastulorum	1	0	0	0	0	0	1	5.15

Appendix 4:4 (Continued)

Species	A	B	C	D	E	F	Total	G statis-tics
Neosebastes scorpaenoides	0	0	1	0	0	0	1	3.80
Chelidonichthys kumu	0	0	1	1	0	0	2	4.43
Pterygotrigla polyommata	0	0	0	0	1	0	1	3.59
Platycephalus laevigatus	0	0	2	1	0	0	3	7.20
Platycephalus bassensis	0	19	11	18	8	0	56	20.06
Platycephalus castelnaui	0	2	1	0	5	0	8	11.27
Acanthopegasus lancifer	0	1	0	0	0	0	1	1.91
Nannoperca australis	2	0	1	0	0	0	3	10.30
Siphamia cephalotes	0	1	0	0	0	0	1	1.91
Apogon conspersus	0	0	1	2	0	0	3	6.80
Sillago bassensis	0	1	0	3	4	0	8	10.97
Pomatomus saltator	0	0	4	1	0	0	5	13.68
Caranx georgianus	0	7	6	3	1	0	17	9.10
Trachurus declivis	0	1	1	0	1	0	3	2.71
Arripis trutta	6	78	28	41	84	19	256	94.54
Parequula melbournensis	0	0	0	0	1	0	1	3.59
Acanthopagrus butcheri	5	13	1	0	0	0	19	25.71
Upeneus tragula	0	1	0	0	0	0	1	1.91
Atypichthys strigatus	0	2	0	0	0	0	2	3.83
Girella tricuspidata	0	0	10	1	1	0	12	32.03
Enoplosus armatus	0	1	0	1	1	0	3	2.31
Nemadactylus macropterus	0	1	0	1	0	0	2	2.54
Latridopsis forsteri	0	1	0	0	0	0	1	1.91
Mugil cephalus	0	1	2	0	0	0	3	5.70
Myxus elongatus	1	6	3	2	6	0	18	4.71
Aldrichetta forsteri	13	178	60	84	78	12	425.1	35.48
Pseudolabrus tetricus	0	3	0	3	2	0	8	5.83
Neodax radiatus	0	1	0	2	0	0	3	4.91
Neodax semifasciatus	0	1	0	15	2	0	18	41.25
Neodax balteatus	1	13	5	42	3	0	64	82.52
Siphonognathus argyrophanes	0	0	0	1	0	0	1	3.40
Kathetostoma laeve	0	0	0	6	1	0	7	18.43
Crapatalus sp.	0	4	1	2	17	2	26	37.36
Crapatalus arenarius	0	5	0	4	37	16	62	147.86
Bovichthys variegatus	0	2	1	2	0	0	5	3.88
Pseudaphritis urvillii	13	60	29	9	0	0	111	76.92
Ophiclinus gracilis	0	0	0	0	3	0	3	10.82
Cristiceps australis	0	15	10	17	1	0	43	29.44
Cristiceps argyropleura	0	2	0	0	0	0	2	3.83
Heteroclinus forsteri	0	2	0	0	0	0	2	3.83
Heteroclinus perspicillatus	0	21	11	33	3	0	68	53.64
Heteroclinus macrophthalmus	0	1	0	1	0	0	2	2.54
Heteroclinus wilsoni	0	3	0	0	0	0	3	5.75
Pictiblennius tasmanianus	0	1	0	2	0	0	3	4.91
Amoya bifrenatus	0	0	10	1	0	0	11	35.35

Appendix 4:4 (Continued)

Species	A	B	C	D	E	F	Total	G statistics
Amoya frenatus	0	0	0	2	0	0	2	6.82
Callogobius mucosus	0	0	0	1	0	0	1	3.40
Favonigobius tamarensis	4	46	40	9	0	0	99	89.42
Favonigobius lateralis	0	17	15	5	2	0	39	25.43
Favonigobius sp.	0	1	0	0	0	0	1	1.91
Nesogobius hinsbyi	0	15	2	21	4	0	42	32.81
Nesogobius pulchellus	0	1	1	3	0	0	5	6.44
Nesogobius sp.2	6	124	37	110	14	0	291	194.10
Nesogobius sp.3	0	1	0	0	0	0	1	1.91
Nesogobius sp.5	0	7	10	6	0	0	23	22.87
Nesogobius sp.7	0	0	0	7	0	0	7	24.07
Pseudogobius olorum	10	23	19	1	0	0	53	55.16
Tasmanogobius lordi	1	10	8	4	0	0	23	14.70
Tasmanogobius sp.3	0	0	0	1	0	0	1	3.40
Tasmanogobius sp.	7	26	5	4	0	0	42	29.22
Seriolella brama	0	0	0	1	0	0	1	3.40
Callionymus calauropomus	0	0	0	1	0	0	1	3.40
Arnoglossus bassensis	0	2	0	1	0	0	3	3.41
Ammotretis rostratus	10	126	25	66	47	3	277	44.38
Ammotretis liturata	0	4	1	1	33	9	48	110.35
Taratretis derwentensis	0	2	0	2	10	0	14	24.75
Rhombosolea tapirina	10	164	59	103	23	3	362	136.49
Eubalichthys gunnii	0	0	0	1	0	0	1	3.40
Penicipelta vittiger	0	9	1	11	0	0	21	23.38
Acanthaluteres spilomelanurus	0	32	17	60	8	0	117	104.16
Brachaluteres jacksonianus	0	3	3	4	0	0	10	9.02
Meuschenia freycineti	0	14	13	22	2	0	51	38.64
Aracana aurita	0	1	0	3	1	0	5	6.23
Torquigener glaber	0	48	25	24	6	0	103	45.65
Contusus richei	0	11	10	6	9	0	36	13.95
Contusus sp.	0	4	2	14	10	0	30	29.51
Diodon nicthemerus	0	3	2	9	2	0	16	14.38
Dicotylichthys myersi	0	0	2	0	0	0	2	7.62

Appendix 4:5. Standard residuals for species with significant G-statistics for major habitat types.

Species	A	B	C	D	E	F	G-statistics
Retropinna tasmanica	-1.36	2.40	4.63	-2.78	-3.01	-1.36	46.43
Galaxias maculatus	.97	4.67	5.15	-5.17	-5.10	-2.42	111.43
Galaxias truttaceus	1.11	.78	-.85	2.05	-2.54	-1.15	17.83
Anguilla australis	1.57	- .03	5.35	-2.82	-2.66	-1.20	44.66
Hyporhamphus melanochir	-1.85	-1.35	-1.31	3.77	.66	-.44	18.42
Taratretis derwentensis	-1.09	-1.68	-1.59	-.39	5.55	-.76	24.75
Ammotretis rostratus	-3.16	2.98	-3.46	2.96	.18	-3.01	44.38
Ammotretis liturata	-2.06	-4.43	-2.59	-3.00	10.00	5.47	110.35
Rhombosolea tapirina	-4.77	3.63	.93	6.79	-7.13	-4.10	136.49
Hippocampus breviceps	-.77	-2.10	-1.12	3.65	.85	-.54	15.93
Leptonotus semistriatus	-.22	-2.16	-1.70	4.62	.23	-.82	20.86
Syngnathus tuckeri	-1.05	-2.87	-1.53	.45	5.13	.71	28.91
Stigmatopora argus	-2.35	-1.77	1.81	5.12	-2.20	-1.64	40.45
Stigmatopora nigra	-2.67	1.57	3.84	1.22	-4.13	-1.86	58.36
Syngnathus phillipi	-1.53	-1.36	3.81	2.06	-2.36	-1.07	28.11
Urocampus carinirostris	1.81	-2.02	5.66	-1.85	-1.75	-.79	32.06
Aldrichetta forsteri	-5.26	2.13	-.75	1.16	1.39	-1.70	35.48
Atherinason sp.	-1.40	-.80	-2.05	5.36	-1.04	-.98	28.72
Atherinason esox	-1.95	-5.01	-2.83	12.63	-1.75	-1.36	123.36
Atherinosoma microstoma	4.13	1.40	5.74	.30	-8.51	-4.02	156.64
Atherinosoma presbyteroides	-5.50	-2.41	-1.82	11.44	-.94	-4.04	170.53
Platycephalus bassensis	-2.24	-.72	1.01	2.78	-.49	-1.57	20.06
Gymnapistes marmoratus	-2.24	-1.93	3.41	6.16	-4.44	-2.13	76.42
Acanthopagrus butcheri	3.08	2.72	-1.20	-2.09	-1.97	-.89	25.71
Girella tricuspidata	-1.01	-2.76	6.68	-.90	-.78	-.70	32.03
Arripis trutta	-3.90	-3.19	-2.22	-1.14	8.44	3.52	94.54
Crapatalus arenarius	-2.37	-5.12	-3.45	-2.51	9.47	9.27	147.86
Crapatalus sp.	-1.50	-2.46	-1.62	-1.42	6.78	1.01	37.36
Kathetostoma laeve	-.77	-2.10	-1.12	4.64	-.17	-.54	18.43
Pseudaphritis urvillii	1.71	3.64	3.54	-2.99	-5.08	-2.29	76.92
Favonigobius tamarensis	-1.46	1.75	7.56	-2.53	-4.75	-2.15	89.42
Amoya bifrenatus	-.96	-2.64	7.10	-.79	-1.49	-.67	35.35
Favonigobius lateralis	-1.85	.68	4.21	-.91	-1.98	-1.29	25.43
Nesogobius hinsbyi	-1.92	-.38	-1.91	5.46	-1.27	-1.34	32.81
Nesogobius sp.7	-.77	-2.10	-1.12	5.62	-1.19	-.54	24.07
Nesogobius sp.5	-1.40	-.80	3.88	.98	-2.17	-.98	22.87
Nesogobius sp.2	-4.53	1.83	-1.38	10.82	-6.81	-4.32	194.10
Pseudogobius olorum	3.16	.76	4.40	-3.20	-3.37	-1.52	55.16
Tasmanogobius sp 3	2.24	3.21	-.58	-1.51	-2.98	-1.34	29.22
Heteroclinus perspicillatus	-2.49	-1.34	.28	6.75	-2.83	-1.74	53.64
Cristiceps australis	-1.95	-.50	1.56	3.71	-2.59	-1.36	29.44
Neoodax semifasciatus	-1.24	-2.90	-1.80	7.22	-.64	-.87	41.25
Neoodax balteatus	-1.92	-3.11	-1.68	10.22	-2.68	-1.68	82.52
Torquigener glaber	-3.14	1.82	2.82	1.41	-3.16	-2.19	45.65
Contusus sp.	-1.61	-2.88	-1.30	4.10	2.50	-1.13	29.51
Penicipelta vittiger	-1.34	.42	-1.33	4.10	-2.08	-.94	23.38
Acanthaluteres spilomelanurus	-3.38	-2.68	-.16	10.00	-3.08	-2.36	104.16
Meuschenia freycineti	-2.13	-1.67	2.47	4.75	-2.52	-1.49	38.64

Appendix 4:6 : Similarity matrices for cluster analysis of shore zone sedimentary habitats. a. 6 major habitats, all species included. b. 6 major habitats, widespread species removed. c. 5 habitats, all species included.

1	Closed estuaries	-					
2	Open estuaries (lower)	23.9	-				
3	Sheltered beaches	20.7	56.6	-			
4	Open estuaries (upper)	31.4	54.9	49.0	-		
5	Semi-exposed beaches	17.1	45.1	48.0	35.5	-	
6	Exposed beaches	17.2	9.9	11.5	11.4	17.2	-
		1	2	3	4	5	6

1	Closed estuaries	-					
2	Open estuaries (lower)	17.6	-				
3	Sheltered beaches	14.1	53.8	-			
4	Open estuaries (upper)	23.8	51.6	45.4	-		
5	Semi-exposed beaches	7.9	41.1	44.0	30.2	-	
6	Exposed beaches	0.0	4.8	6.3	4.8	9.8	-
		1	2	3	4	5	6

1	Closed systems	-				
2	Tidal rivers	42.9	-			
3	Bay estuaries	22.0	34.7	-		
4	Sheltered beaches	22.2	39.5	54.9	-	
5	Exposed beaches	16.1	36.2	34.3	38.8	-
		1	2	3	4	5

Appendix 4:7. Distribution of species at estuarine, sheltered beach and exposed beach habitats.

Species	Estuaries	G-statistics	Sheltered beaches	G-statistics	Exposed beaches	G-statistics
Geotria australis	1	8.96	0	0	0	0
Squalus acanthias	0	0	0	0	1	4.14
Narcine tasmaniensis	0	0	0	0	1	3.41
Raja lemprieri	0	0	0	0	1	3.41
Raja whitleyi	0	0	2	5.33	0	0
Urolophus cruciatus	2	12.19	1	2.45	1	3.41
Urolophus paucimaculatus	1	6.05	0	0	1	3.41
Myliobatis australis	1	6.05	0	0	0	0
Spratelloides robustus	6	21.88	5	6.17	4	8.46
Engraulis australis	7	21.60	3	4.42	1	3.41
Anguilla reinhardtii	2	12.24	0	0	0	0
Anguilla australis	34	77.74	0	0	0	0
Muraenichthys breviceps	0	0	1	2.65	0	0
Salmo trutta	2	13.34	0	0	0	0
Retropinna tasmanica	42	108.56	1	3.47	0	0
Prototroctes maraena	9	47.51	0	0	0	0
Lovettia sealii	15	33.77	4	9.05	0	0
Galaxias truttaceus	21	46.05	10	7.21	0	0
Galaxias maculatus	119	133.81	2	3.33	1	4.14
Pseudophycis bachus	5	16.90	5	4.71	1	4.14
Genypterus sp.	2	12.55	0	0	0	0
Brachionichthys hirsutus	1	6.05	0	0	0	0
Hyporhamphus melanochir	14	41.25	16	10.54	9	7.40
Atherinosoma microstoma	213	120.39	50	12.93	2	10.76
Atherinosoma presbyteroides	138	136.07	115	13.00	46	27.01
Atherinason esox	1	7.48	39	13.71	3	11.75
Atherinason sp.	7	30.37	14	11.55	2	4.09
Atherinason hepsetoides	3	13.95	2	5.33	3	3.88
Cyttus australis	0	0	0	0	1	3.41
Hypselognathus rostratus	0	0	1	2.45	0	0
Lissocampus runa	0	0	3	8.05	0	0
Urocampus carinirostris	15	53.05	0	0	0	0
Leptonotus costatus	1	6.23	0	0	0	0
Leptonotus semistriatus	3	12.43	10	12.67	3	5.79
Leptoichthys fistularius	0	0	1	2.45	0	0
Syngnathus tuckeri	0	0	3	10.61	10	5.62
Syngnathus curtirostris	1	7.48	1	2.45	1	5.90
Syngnathus phillipi	18	48.34	9	4.04	0	0
Syngnathus poecilolaemus	1	6.05	0	0	1	5.90
Stigmatopora nigra	59	104.72	18	6.99	0	0
Stigmatopora argus	31	71.61	26	10.02	4	14.82
Hippocampus abdominalis	10	30.09	1	3.47	0	0
Hippocampus breviceps	0	0	5	3.07	2	7.26
Alabes parvulus	0	0	1	2.45	0	0
Alabes dorsalis	1	4.73	0	0	0	0
Gymnapistes marmoratus	57	72.36	40	.67	1	3.41
Scorpaena ergastulorum	1	6.76	0	0	0	0

Appendix 4:7 (Continued)

Species	Estuaries	G-statistics	Sheltered beaches	G-statistics	Exposed beaches	G-statistics
Neosebastes scorpaenoides	1	6.88	0	0	0	0
Chelidonichthys kumu	1	6.23	1	3.47	0	0
Pterygotrigla polyommata	0	0	0	0	1	3.41
Platycephalus laevigatus	2	12.55	1	2.45	0	0
Platycephalus bassensis	30	63.29	18	9.78	8	4.72
Platycephalus castelnaui	3	17.26	0	0	5	10.57
Acanthopegasus lancifer	1	4.73	0	0	0	0
Nannoperca australis	3	16.30	0	0	0	0
Siphamia cephalotes	1	7.48	0	0	0	0
Apogon conspersus	1	6.05	2	5.33	0	0
Sillago bassensis	1	7.02	3	10.61	4	7.18
Pomatomus saltator	4	20.51	1	3.47	0	0
Caranx georgianus	13	37.08	3	3.93	1	3.55
Trachurus declivis	2	8.18	0	0	1	2.73
Arripis trutta	112	88.25	41	2.80	103	20.72
Parequula melbournensis	0	0	0	0	1	3.55
Acanthopagrus butcheri	19	44.03	0	0	0	0
Upeneus tragula	1	4.73	0	0	0	0
Atypichthys strigatus	2	6.68	0	0	0	0
Girella tricuspidata	10	49.28	1	3.81	1	3.41
Enoplosus armatus	1	7.48	1	2.45	1	4.14
Nemadactylus macropterus	1	6.05	1	3.81	0	0
Latridopsis forsteri	1	7.02	0	0	0	0
Mugil cephalus	3	13.09	0	0	0	0
Myxus elongatus	10	29.34	2	4.93	6	13.35
Aldrichetta forsteri	251	157.00	84	10.40	90	13.07
Pseudolabrus tetricus	3	11.27	3	6.30	2	6.67
Neoodax radiatus	1	7.48	2	4.93	0	0
Neoodax semifasciatus	1	7.48	15	10.43	2	6.67
Neoodax balteatus	19	39.05	42	10.44	3	10.93
Siphonognathus argyrophanes	0	0	1	2.45	0	0
Kathetostoma laeve	0	0	6	2.77	1	2.73
Crapatalus sp.	5	26.44	2	2.31	19	8.90
Crapatalus arenarius	5	21.99	4	3.71	53	16.52
Bovichthys variegatus	3	11.38	2	2.31	0	0
Pseudaphritis urvillii	102	104.54	9	12.72	0	0
Ophiclinus gracilis	0	0	0	0	3	10.85
Cristiceps australis	25	50.48	17	1.26	1	4.14
Cristiceps argyropleura	2	9.50	0	0	0	0
Heteroclinus forsteri	2	9.50	0	0	0	0
Heteroclinus perspicillatus	32	62.11	33	7.07	3	10.93
Heteroclinus macrophthalmus	1	7.48	1	2.65	0	0
Heteroclinus wilsoni	3	10.41	0	0	0	0
Pictiblennius tasmanianus	1	7.02	2	5.28	0	0
Amoya bifrenatus	10	40.94	1	3.47	0	0

Appendix 4:7 (Continued)

Species	Estuaries	G-statistics	Sheltered beaches	G-statistics	Exposed beaches	G-statistics
Amoya frenatus	0	0	2	4.26	0	0
Callogobius mucosus	0	0	1	4.60	0	0
Favonigobius tamarensis	90	80.12	9	18.22	0	0
Favonigobius lateralis	32	70.25	5	6.25	2	6.53
Favonigobius sp.	1	4.73	0	0	0	0
Nesogobius hinsbyi	17	34.91	21	10.70	4	8.27
Nesogobius pulchellus	2	8.18	3	3.73	0	0
Nesogobius sp.2	167	180.60	110	8.31	14	32.03
Nesogobius sp.3	1	7.48	0	0	0	0
Nesogobius sp.5	17	49.71	6	6.58	0	0
Nesogobius sp.7	0	0	7	6.77	0	0
Pseudogobius olorum	52	76.50	1	3.81	0	0
Tasmanogobius lordi	19	45.31	4	10.67	0	0
Tasmanogobius sp.1	0	0	1	3.47	0	0
Tasmanogobius sp.3	38	56.43	4	5.86	0	0
Seriolella brama	0	0	1	2.65	0	0
Callionymus calauropomus	0	0	1	2.65	0	0
Arnoglossus bassensis	2	8.01	1	3.47	0	0
Ammotretis rostratus	161	119.39	66	4.07	50	16.21
Ammotretis liturata	5	20.63	1	3.47	42	12.36
Taratretis derwentensis	2	10.29	2	3.13	10	13.71
Rhombosolea tapirina	233	123.67	103	7.70	26	8.98
Eubalichthys gunnii	0	0	1	2.45	0	0
Penicipelta vittiger	10	26.96	11	9.19	0	0
Acanthaluteres spilomelanurus	49	102.22	60	7.83	8	17.07
Brachaluteres jacksonianus	6	19.11	4	8.11	0	0
Meuschenia freycineti	27	69.08	22	3.15	2	5.85
Aracana aurita	1	4.73	3	4.95	1	3.41
Torquigener glaber	73	101.52	24	1.60	6	4.31
Contusus richei	21	65.71	6	7.05	9	7.26
Contusus sp.	6	19.92	14	11.76	10	12.59
Diodon nicthemerus	5	15.91	9	.54	2	10.04
Dicotylichthys myersi	2	12.55	0	0	0	0

Appendix 4:8 : Factor scores for rotated factors based on estuarine habitats.

Habitat Type	Factor 1	2	3	4	5
Coastal lakes	-.211	-1.497	-.502	1.234	-2.194
Bar-dammed lagoons (lower)	-1.015	1.844	-.225	1.243	-.100
Bar-dammed lagoons (middle and upper)	-.535	.407	-.299	.171	.436
Bar-dammed lagoons (open)	-.381	.237	-.265	-.262	-1.368
Bar-dammed rivers (lower)	-.700	1.699	-.943	.751	-.694
Bar-dammed rivers (open)	.085	-.448	-.319	-.104	-.713
Beach-dammed rivers (lower)	-1.342	1.297	-.303	1.352	.855
Beach-dammed rivers (middle and upper)	-.987	.313	-.755	.791	1.380
Beach-dammed rivers (open)	-.137	-.605	.032	-.517	-1.076
Open lagoons (bar)	-.166	-.716	.509	.063	.447
Open lagoons (mouth)	1.337	-1.620	-.331	.073	.799
Open lagoons (mid-lower)	2.651	-1.065	.035	.232	1.495
Open lagoons (mid)	-.627	-1.566	-.681	.935	.710
Open lagoons (mid-upper)	-.165	1.296	.080	-3.389	.315
Open lagoons (pre-riffle)	1.672	-1.472	-1.473	-.191	1.545
Bay estuaries, deep (mouth)	.583	-.037	.298	.110	2.162
Bay estuaries, deep (mid-lower)	-.428	-.144	-.428	.770	.197
Bay estuaries, deep (mid)	-1.059	-1.055	-.842	1.165	.035
Bay estuaries, deep (mid-upper)	-1.046	-.281	-.715	-.142	.168
Bay estuaries, deep (pre-riffle)	-.968	.411	-.329	.600	.822
Bay estuaries, flats (mouth)	-.178	-.834	.306	.177	-.890
Bay estuaries, flats (mid-lower)	-.688	.772	-.550	-1.085	.544
Bay estuaries, flats (mid)	.146	-.406	.473	.235	-1.089
Bay estuaries, flats (mid-upper)	.213	-.130	5.278	1.284	.379
Bay estuaries, flats (pre-riffle)	3.406	2.573	-.335	1.036	-.635
Tidal rivers (bar)	2.052	1.951	-.723	1.078	-.403
Tidal rivers (mouth)	.350	-.370	-.573	-2.322	.224
Tidal rivers (mid-lower)	-.070	.001	.343	-.598	.147
Tidal rivers (mid)	.291	.200	.699	-2.298	-.909
Tidal rivers (mid-upper)	-.238	.164	.783	-.781	1.033
Tidal rivers (pre-riffle)	-.245	-.485	.271	.009	.832
Tidal rivers (post-riffle)	-.003	.158	.552	-.218	-1.087
Tidal creeks (bar)	-1.211	.918	.650	-.364	1.878
Tidal creeks (mouth)	-.368	.713	-.090	-.391	.263
Tidal creeks (mid-lower)	.167	-.595	-.095	-.153	-.806
Tidal creeks (mid)	-.007	-.585	-.218	.496	-.703
Tidal creeks (pre-riffle)	-.136	-.384	-.251	-.091	-.907
Tidal creeks (post-riffle)	.150	-.764	-.164	-.168	-.763
Tidal tributaries (lower)	.059	-.565	.656	-.280	-.914
Tidal tributaries (upper)	-.246	.675	.452	-.453	-1.419

Appendix 4:9. Distribution of species on salinity characteristics.

Species	less than 1 ppt	1-5 ppt	5-18 ppt	18-30 ppt	30-36 ppt	36-45 ppt	Greater than 45 ppt	Total	G-statistics	Classification
Geotria australis	1	0	0	0	0	0	0	1	4.85	E3
Squalus acanthias	0	0	0	0	1	0	0	1	1.03	E3
Narcine tasmaniensis	0	0	0	0	1	0	0	1	1.03	SM
Raja lemprieri	0	0	0	0	1	0	0	1	1.03	SM
Raja whitleyi	0	0	0	0	2	0	0	2	2.06	SM
Urolophus cruciatus	0	0	0	2	2	0	0	4	3.65	E1
Urolophus paucimaculatus	0	0	0	1	1	0	0	2	1.82	E1
Myliobatis australis	0	0	0	1	0	0	0	1	3.57	E1
Spratelloides robustus	0	0	0	1	14	0	0	15	10.76	E1
Engraulis australis	0	1	2	2	5	0	0	10	3.71	E3
Anguilla reinhardtii	1	0	0	0	0	0	0	1	4.85	E3
Anguilla australis	4	0	5	8	7	0	0	24	13.07	E3
Muraenichthys breviceps	0	0	0	0	1	0	0	1	1.03	E1
Salmo trutta	0	0	2	0	0	0	0	2	9.04	E3
Retropinna tasmanica	4	5	17	10	3	0	0	39	63.15	E3
Prototroctes maraena	8	1	0	0	0	0	0	9	40.18	SF
Lovettia sealii	3	1	3	3	5	0	0	15	5.39	E3
Galaxias truttaceus	11	2	7	0	9	0	0	29	36.40	E3
Galaxias maculatus	35	14	25	17	10	0	0	101	173.09	E3
Pseudophycis bachus	0	0	0	2	9	0	0	11	5.99	E1
Genypterus sp.	0	0	0	0	2	0	0	2	2.06	E1
Brachionichthys hirsutus	0	0	0	1	0	0	0	1	3.57	E1
Hyporhamphus melanochir	0	0	0	2	37	0	0	39	30.52	E2
Atherinosoma microstoma	10	10	42	59	104	2	2	229	63.51	H3
Atherinosoma presbyteroides	1	7	19	43	224	0	0	294	94.51	E3
Atherinason esox	0	0	1	3	39	0	0	43	25.25	E2
Atherinason sp.	0	0	0	4	19	0	0	23	12.75	E1
Atherinason hepsetoides	0	0	0	2	6	0	0	8	4.32	E1
Cyttus australis	0	0	0	0	1	0	0	0	1.03	SM
Hypselognathus rostratus	0	0	0	0	1	0	0	1	1.03	SM
Lissocampus runa	0	0	0	0	3	0	0	3	3.09	SM
Urocampus carinirostris	0	1	4	3	6	0	0	14	7.08	E3
Leptonotus costatus	0	0	0	0	1	0	0	1	1.03	SM
Leptonotus semistriatus	0	0	0	1	15	0	0	16	11.68	E1
Leptoichthys fistularius	0	0	0	0	1	0	0	1	1.03	SM
Syngnathus tuckeri	0	0	0	0	3	0	0	13	13.52	SM
Syngnathus curtirostris	0	0	0	0	3	0	0	3	3.09	SM
Syngnathus phillipi	0	0	0	2	25	0	0	27	19.04	E1
Syngnathus poecilolaemus	0	0	0	0	2	0	0	2	2.06	SM
Stigmatopora nigra	0	0	5	16	52	0	0	73	23,63	E2
Stigmatopora argus	0	0	2	8	49	0	0	59	25.53	E2
Hippocampus abdominalis	0	0	1	5	4	0	0	10	7.65	E2
Hippocampus breviceps	0	0	0	0	7	0	0	7	7.24	SM
Alabes parvulus	0	0	0	0	1	0	0	1	1.03	SM
Alabes dorsalis	0	0	0	0	1	0	0	1	1.03	E1
Gymnapistes marmoratus	1	1	10	12	67	0	0	91	17.98	E3
Scorpaena ergastulorum	0	0	0	0	0	1	0	1	12.41	H1

Appendix 4:9 (Continued)

Species	less than 1 ppt	1 - 5 ppt	5-18 ppt	18-30 ppt	30-36 ppt	36-45 ppt	Greater than 45 ppt	Total	G-statistics	Classification
Neosebastes scorpaenoides	0	0	0	1	0	0	0	1	3.57	E2
Chelidonichthys kumu	0	0	0	0	2	0	0	2	2.06	SM
Pterygotrigla polyommata	0	0	0	0	1	0	0	1	1.03	E1
Platycephalus laevigatus	0	0	0	0	3	0	0	3	3.09	E1
Platycephalus bassensis	0	0	2	8	45	0	0	55	22.70	E2
Platycephalus castelnaui	0	0	1	0	7	0	0	8	5.70	E2
Acanthopegasus lancifer	0	0	0	0	1	0	0	1	1.03	E1
Nannoperca australis	2	0	1	0	0	0	0	3	10.41	E5
Siphamia cephalotes	0	0	0	0	1	0	0	1	1.03	SM
Apogon conspersus	0	0	0	0	3	0	0	3	3.09	E1
Sillago bassensis	0	0	0	1	7	0	0	8	4.76	E1
Pomatomus saltator	0	0	0	0	5	0	0	5	5.16	E1
Caranx georgianus	0	0	0	7	10	0	0	17	12.40	E1
Trachurus declivis	0	0	0	0	3	0	0	3	3.09	E1
Arripis trutta	0	1	14	34	189	0	0	238	97.91	E3
Parequula melbournensis	0	0	0	0	1	0	0	1	1.03	SM
Acanthopagrus butcheri	0	0	2	4	5	0	0	11	5.65	E3
Upeneus tragula	0	0	0	0	1	0	0	1	1.03	SM
Atypichthys strigatus	0	0	0	1	1	0	0	2	1.82	E1
Girella tricuspidata	0	0	0	4	8	0	0	12	7.26	E2
Enoplosus armatus	0	0	0	0	3	0	0	3	3.09	SM
Nemadactylus macropterus	0	0	0	1	1	0	0	2	1.82	E1
Latridopsis forsteri	0	0	0	0	1	0	0	1	1.03	E1
Mugil cephalus	0	0	0	1	2	0	0	3	1.80	E3
Myxus elongatus	0	1	0	2	15	0	0	18	9.48	E3
Aldrichetta forsteri	9	7	36	67	271	1	0	391	68.38	H3
Pseudolabrus tetricus	0	0	0	1	7	0	0	8	4.76	E1
Neoodax radiatus	0	0	0	0	3	0	0	3	3.09	SM
Neoodax semifasciatus	0	0	0	0	18	0	0	18	18.81	SM
Neoodax balteatus	0	0	2	4	55	1	0	62	37.09	H2
Siphonognathus argyrophanes	0	0	0	0	1	0	0	1	1.03	SM
Kathetostoma laeve	0	0	0	0	7	0	0	7	7.24	SM
Crapatalus sp.	0	0	0	1	25	0	0	26	16.28	E1
Crapatalus arenarius	0	0	0	2	59	0	0	61	46.37	E1
Bovichthys variegatus	0	0	0	0	4	0	0	5	3.62	E2
Pseudaphritis urvillii	10	7	21	26	24	0	0	88	49.31	E3
Ophiclinus gracilis	0	0	0	0	3	0	0	3	3.09	SM
Cristiceps australis	0	0	1	3	38	0	0	42	24.35	E2
Cristiceps argyropleura	0	0	0	0	2	0	0	2	2.06	SM
Heteroclinus forsteri	0	0	0	0	2	0	0	2	2.06	SM
Heteroclinus perspicillatus	0	0	1	4	61	0	0	66	43.97	E2
Heteroclinus macrophthalmus	0	0	0	0	2	0	0	2	2.06	SM
Heteroclinus wilsoni	0	0	0	0	3	0	0	3	3.09	SM
Pictiblennius tasmanianus	0	0	0	0	3	0	0	3	3.09	E1
Amoya bifrenatus	0	0	2	3	6	0	0	11	3.99	E3

Appendix 4:9 (Continued)

Species	less than 1 ppt	1 - 5 ppt	5-18 ppt	18-30 ppt	30-36 ppt	36-45 ppt	Greater than 45 ppt	Total	G-statistics	Classification
Amoya frenatus	0	0	0	0	2	0	0	2	2.06	SM
Callogobius mucosus	0	0	0	0	1	0	0	1	1.03	E1
Favonigobius tamarensis	5	3	14	26	36	0	0	84	19.19	E3
Favonigobius lateralis	0	0	6	7	25	0	0	38	11.15	E2
Favonigobius sp.	1	0	0	0	0	0	0	1	4.85	SF
Nesogobius hinsbyi	0	0	1	9	30	0	0	40	16.45	E2
Nesogobius pulchellus	0	0	0	0	5	0	0	5	5.16	SM
Nesogobius sp.2	2	2	18	60	197	0	0	279	83.93	E3
Nesogobius sp.3	0	0	0	0	1	0	0	1	1.03	SM
Nesogobius sp.5	0	0	1	6	15	0	0	22	8.17	E2
Nesogobius sp.7	0	0	0	0	7	0	0	7	7.24	SM
Pseudogobius olorum	1	2	12	12	10	0	0	37	28.01	E3
Tasmanogobius lordi	2	1	6	3	5	0	0	17	10.23	E3
Tasmanogobius sp.1	0	0	0	0	1	0	0	1	1.03	SM
Tasmanogobius sp.3	9	0	15	10	2	0	0	36	63.67	E3
Seriolella brama	0	0	0	0	1	0	0	1	1.03	E1
Callionymus calauropomus	0	0	0	0	1	0	0	1	1.03	SM
Arnoglossus bassensis	0	0	0	1	2	0	0	3	1.80	E1
Ammotretis rostratus	11	7	15	40	187	0	0	260	35.08	E3
Ammotretis liturata	0	0	0	2	45	0	0	47	32.26	E1
Taratretis derwentensis	0	0	0	1	13	0	0	14	9.85	E1
Rhombosolea tapirina	10	6	38	70	217	0	0	341	45.47	E3
Eubalichthys gunnii	0	0	0	0	1	0	0	1	1.03	SM
Penicipelta vittiger	0	0	0	0	21	0	0	21	22.01	SM
Acanthaluteres spilomelanurus	0	1	3	10	99	0	0	113	58.67	E3
Brachaluteres jacksonianus	0	0	0	0	10	0	0	10	10.37	E1
Meuschenia freycineti	0	2	1	5	42	0	0	50	21.82	E3
Aracana aurita	0	0	0	1	4	0	0	5	2.68	E1
Torquigener glaber	0	0	8	24	68	0	0	100	32.62	E2
Contusus richei	0	0	2	5	29	0	0	36	13.18	E2
Contusus sp.	0	0	0	4	26	0	0	30	17.87	E1
Diodon nicthemerus	0	0	0	2	16	0	0	16	9.59	E1
Dicotylichthys myersi	0	0	0	0	2	0	0	2	2.06	SM

Appendix 4:10 : Distribution of species according to substrate type

	Occurrence						
	Pebbles	Sand/ mud	Fresh water/ Brackish plants	Sea grasses	Algae only	Total	G-Statistics
Geotria australis	1	0	0	0	0	1	15.35
Squalus acanthias	0	1	0	0	0	1	1.63
Narcine tasmaniensis	0	1	0	0	0	1	1.63
Raja lemprieri	0	1	0	0	0	1	1.63
Raja whitleyi	0	0	0	2	0	2	3.59
Urolophus cruciatus	0	3	0	1	0	4	2.19
Urolophus paucimaculatus	0	2	0	0	0	2	3.27
Myliobatis australis	0	1	0	0	0	1	1.63
Spratelloides robustus	0	3	0	12	0	15	11.55
Engraulis australis	0	0	0	11	0	11	19.92
Anguilla reinhardtii	1	0	1	0	0	2	19.45
Anguilla australis	1	1	4	24	4	34	40.72
Muraenichthys breviceps	0	0	0	1	0	1	1.79
Salmo trutta	0	2	0	0	0	2	3.27
Retropinna tasmanica	0	21	2	17	3	43	1.50
Prototroctes maraena	0	6	0	2	1	9	2.44
Lovettia sealii	0	14	0	4	1	19	7.57
Galaxias truttaceus	1	10	1	17	2	31	9.88
Galaxias maculatus	1	52	9	44	16	122	10.83
Pseudophycis bachus	0	4	0	7	0	11	4.68
Genypterus sp.	0	0	0	2	0	2	3.59
Brachionichthys hirsutus	0	1	0	0	0	1	1.63
Hyporhamphus melanochir	0	10	0	28	1	39	18.49
Atherinosoma microstoma	0	71	11	162	21	265	74.04
Atherinosoma presbyteroides	0	107	1	175	16	299	79.04
Atherinason esox	0	3	0	40	0	43	57.54
Atherinason sp.	0	4	0	17	2	23	11.90
Atherinason hepsetoides	0	3	0	3	2	8	1.62
Cyttus australis	0	1	0	0	0	1	1.63
Hypselognathus rostratus	0	0	0	1	0	1	1.79
Lissocampus runa	0	0	0	3	0	3	5.39
Urocampus carinirostris	0	3	2	10	0	15	10.85
Leptonotus costatus	0	0	0	1	0	1	1.79
Leptonotus semistriatus	0	0	0	13	3	16	21.12
Leptoichthys fistularius	0	0	0	1	0	1	1.79
Syngnathus tuckeri	0	1	0	7	5	13	12.68
Syngnathus curtirostris	0	0	0	3	0	3	5.39
Syngnathus phillipi	0	0	0	27	0	27	49.72
Syngnathus poecilolaemus	0	0	0	2	0	2	3.59
Stigmatopora nigra	0	6	0	70	1	77	95.50
Stigmatopora argus	0	1	1	56	3	61	83.22
Hippocampus abdominalis	0	2	1	8	0	11	7.80
Hippocampus breviceps	0	0	0	6	1	7	9.39
Alabes parvulus	0	0	0	1	0	1	1.79

Appendix 4:10 (Continued)

	Pebbles	Sand/ mud	Fresh water/ Brackish plants	Sea grasses	Algae only	Total	G-Statistics
Alabes dorsalis	0	0	0	1	0	1	1.79
Gymnapistes marmoratus	0	5	0	88	5	98	123.01
Scorpaena ergastulorum	0	0	0	1	0	1	1.79
Neosebastes scorpaenoides	0	1	0	0	0	1	1.63
Chelidonichthys kumu	0	0	0	2	0	2	3.59
Pterygotrigla polyommata	0	1	0	0	0	1	1.63
Platycephalus laevigatus	0	0	0	3	0	3	5.39
Platycephalus bassensis	0	23	0	32	1	56	15.08
Platycephalus castelnaui	0	5	0	3	0	8	2.95
Acanthopegasus lancifer	0	0	0	1	0	1	1.79
Nannoperca australis	0	1	2	0	0	3	11.63
Siphamia cephalotes	0	0	0	1	0	1	1.79
Apogon conspersus	0	0	0	3	0	3	5.39
Sillago bassensis	0	1	0	4	3	8	6.26
Pomatomus saltator	0	0	0	5	0	5	9.00
Caranx georgianus	0	3	0	14	0	17	14.38
Trachurus declivis	0	1	0	2	0	3	1.40
Arripis trutta	0	124	1	93	38	256	21.04
Parequula melbournensis	0	0	0	1	0	1	1.79
Acanthopagrus butcheri	0	7	1	10	1	19	1.93
Upeneus tragula	0	0	0	1	0	1	1.79
Atypichthys strigatus	0	0	0	2	0	2	3.59
Girella tricuspidata	0	1	0	11	0	12	14.64
Enoplosus armatus	0	0	0	3	0	3	5.39
Nemadactylus macropterus	0	1	0	1	0	2	0.65
Latridopsis forsteri	0	0	0	1	0	1	1.79
Mugil cephalus	0	0	0	3	0	3	5.39
Myxus elongatus	0	5	0	12	1	18	5.76
Aldrichetta forsteri	0	186	2	200	37	425	41.67
Pseudolabrus tetricus	0	0	0	7	1	8	10.92
Neoodax radiatus	0	0	0	3	0	3	5.39
Neoodax semifasciatus	0	0	0	18	0	18	32.83
Neoodax balteatus	0	1	0	63	0	64	111.93
Siphonognathus argyrophanes	0	0	0	1	0	1	1.79
Kathetostoma laeve	0	1	0	5	1	7	3.79
Crapatalus sp.	0	17	0	5	4	26	8.31
Crapatalus arenarius	0	39	0	8	15	62	33.69
Bovichthys variegatus	0	0	0	5	0	5	9.00
Pseudaphritis urvillii	1	19	9	68	14	111	49.81
Ophiclinus gracilis	0	0	0	1	2	3	6.67
Cristiceps australis	0	0	0	41	2	43	68.97
Cristiceps argyropleura	0	0	0	2	0	2	3.59
Heteroclinus forsteri	0	0	0	2	0	2	3.59
Heteroclinus perspicillatus	0	1	0	67	0	68	120.07
Heteroclinus macrophthalmus	0	0	0	2	0	2	3.59
Heteroclinus wilsoni	0	0	0	3	0	3	5.39

Appendix 4:10 (Continued)

	Pebbles	Sand/ mud	Fresh water/ Brackish plants	Sea grasses	Algae only	Total	G-Statistics
Pictiblennius tasmanianus	0	0	0	3	0	3	5.39
Amoya bifrenatus	0	3	0	8	0	11	6.39
Amoya frenatus	0	0	0	2	0	2	3.59
Callogobius mucosus	0	0	0	1	0	1	1.79
Favonigobius tamarensis	0	27	2	61	9	99	20.43
Favonigobius lateralis	0	13	0	26	0	39	18.77
Favonigobius sp.	0	1	0	0	0	1	1.63
Nesogobius hinsbyi	0	13	0	25	4	42	8.41
Nesogobius pulchellus	0	0	0	5	0	5	9.00
Nesogobius sp.2	0	96	0	182	13	291	111.78
Nesogobius sp.3	0	0	0	1	0	1	1.79
Nesogobius sp.5	0	1	0	22	0	23	33.64
Nesogobius sp.7	0	0	0	7	0	7	12.62
Pseudogobius olorum	0	6	4	35	8	53	30.08
Tasmanogobius lordi	0	14	2	7	0	23	8.90
Tasmanogobius sp.1	0	0	0	1	0	1	1.79
Tasmanogobius sp.3	0	17	4	19	2	42	6.25
Seriolella brama	0	0	0	1	0	1	1.79
Callionymus calauropomus	0	0	0	1	0	1	1,.79
Arnoglossus bassensis	0	3	0	0	0	3	4.90
Ammotretis rostratus	0	143	2	111	21	277	22.77
Ammotretis liturata	0	30	0	5	13	48	31.07
Taratretis derwentensis	0	8	0	5	1	14	1.82
Rhombosolea tapirina	0	167	2	176	17	362	59.07
Eubalichthys gunnii	0	0	0	1	0	1	1.79
Penicipelta vittiger	0	0	0	21	0	21	38.42
Acanthaluteres spilomelanurus	0	1	0	111	5	117	194.67
Brachaluteres jacksonianus	0	0	0	10	0	10	18.09
Meuschenia freycineti	0	0	0	50	1	51	88.80
Aracana aurita	0	1	0	4	0	5	3.81
Torquigener glaber	0	27	1	73	2	103	48.65
Contusus richei	0	12	0	22	2	36	8.34
Contusus sp.	0	10	0	16	4	30	4.18
Diodon nicthemerus	0	3	0	13	0	16	12.95
Dicotylichthys myersi	0	0	0	2	0	2	3.59

APPENDIX

TO CHAPTER 6

Appendix 6:1

Numbers of individuals of species sampled from the seven sampling sites in the Great Swanport Estuary during 1976/77.

Species	Site Number 1	2	3	4	5	6	7	1976/77 Total
Engraulis australis	0	0	2	1	0	2	0	5
Anguilla australis	0	0	0	0	0	0	3	3
Salmo trutta	0	0	0	1	0	0	0	1
Galaxias truttaceus	0	0	5	0	0	0	0	5
Galaxias maculatus	0	0	0	23	76	8	9	116
Pseudophycis bachus	0	1	0	1	0	5	0	7
Genypterus sp.	0	0	0	1	0	0	0	1
Hyporhamphus melanochir	2	241	330	247	26	4	1	851
Atherinosoma microstoma	0	10	183	1374	800	4319	11474	18160
Atherinosoma presbyteroides	0	170	1777	2870	2622	700	29	8168
Urocampus carinirostris	0	1	0	0	4	59	3	67
Syngnathus tuckeri	13	5	0	0	0	0	0	18
Stigmatopora nigra	0	11	15	294	3	98	0	421
Gymnapistes marmoratus	0	1	2	28	9	81	49	170
Scorpaena ergastulorum	0	0	0	12	0	0	0	12
Paratrigla papilio	0	0	0	1	0	0	0	1
Platycephalus bassensis	0	0	3	0	0	0	0	3
Sillago bassensis	0	10	0	0	0	0	0	10
Caranx georgianus	0	0	0	18	0	0	0	18
Arripis trutta	291	393	191	33	14	8	5	935
Acanthopagrus butcheri	0	0	0	5	0	1	3	9
Girella tricuspidata	0	0	0	0	0	0	1	1
Mugil cephalus	1	0	0	0	0	0	0	1
Aldrichetta forsteri	321	311	705	2589	635	378	155	5094
Dotalabrus aurantiacus	0	0	0	1	0	0	0	1
Neoodax balteatus	0	0	0	0	0	13	0	13
Crapatalus arenarius	91	45	0	0	0	0	0	136
Pseudaphritis urvillii	0	0	0	0	1	52	41	94
Cristiceps australis	1	1	1	4	0	4	0	11
Heteroclinus adelaidae	0	0	0	1	0	0	0	1
Favonigobius tamarensis	0	0	2	248	228	181	20	679
Favonigobius lateralis	0	0	0	0	1	0	0	1
Nesogobius hinsbyi	0	0	0	1	0	0	0	1
Nesogobius sp.2	0	0	78	203	9	2	0	292
Pseudogobius olorum	0	0	0	10	4	19	78	111
Tasmanogobius lordi	0	0	0	2	0	0	0	2
Tasmanogobius sp.3	0	0	0	1	7	1	1	10
Ammotretis rostratus	1	15	455	71	6	4	0	552
Ammotretis liturata	21	38	0	0	0	0	0	59
Rhombosolea tapirina	2	13	247	100	151	20	3	536
Penicipelta vittiger	0	0	0	0	6	0	0	6
Acanthaluteres spilomelanurus	0	0	1	2	0	11	0	14
Brachaluteres jacksonianus	0	0	0	8	2	2	0	12
Meuschenia freycineti	0	0	2	7	0	12	0	21
Contusus richei	5	21	0	0	0	0	0	26

Appendix 6:1 (Continued)

Numbers of individuals of species sampled from four sampling sites at day and night in the Great Swanport Estuary during 1977/78.

Species	Site 2 Day	Site 2 Night	Site 3 Day	Site 3 Night	Site 4 Day	Site 4 Night	Site 6 Day	Site 6 Night	Diel Total Day	Diel Total Night	1977/78 Total	1976/78 Total
Mordacia mordax	0	0	0	1	0	0	0	0	0	1	1	1
Urolophus paucimaculatus	0	0	0	1	0	0	0	0	0	1	1	1
Myliobatis australis	0	0	0	0	0	1	0	0	0	1	1	1
Spratelloides robustus	0	0	1	0	0	0	0	0	1	0	1	1
Engraulis australis	5	0	1	0	0	0	9	0	15	0	15	20
Anguilla australis	0	0	0	0	0	0	1	16	1	16	17	20
Salmo trutta	0	0	0	0	0	0	0	0	0	0	0	1
Galaxias truttaceus	0	0	0	0	0	0	0	0	0	0	0	5
Galaxias maculatus	0	0	0	0	2	0	15	1	17	1	18	134
Physiculus bachus	0	0	0	1	0	0	0	0	0	1	1	8
Genypterus sp.	0	0	0	0	0	0	0	0	0	0	0	1
Hyporhamphus melanochir	0	18	5	55	3	21	0	0	8	94	102	953
Atherinosoma microstoma	0	0	17	0	1518	170	1301	349	2836	519	3355	21515
Atherinosoma presbyteroides	837	18	1083	354	844	870	1366	393	4130	1635	5765	13933
Atherinason sp.	0	0	1	0	0	0	0	0	1	0	1	1
Urocampus carinirostris	0	0	0	0	1	1	9	5	10	6	16	83
Syngnathus tuckeri	0	0	0	0	0	0	0	0	0	0	0	18
Stigmatopora nigra	17	0	3	11	306	73	70	16	396	100	496	917
Stigmatopora argus	0	0	0	0	0	0	0	1	0	1	1	1
Gymnapistes marmoratus	1	3	3	7	12	3	5	36	21	49	70	240
Scorpaena ergastulorum	0	0	0	0	0	0	0	0	0	0	0	12
Paratrigla papilio	0	0	0	0	0	0	0	0	0	0	0	1
Platycephalus bassensis	0	2	0	5	1	0	0	0	1	7	8	11
Sillago bassensis	3	0	0	0	0	0	0	0	3	0	3	13
Caranx georgianus	0	7	0	0	0	0	0	0	0	7	7	25
Arripis trutta	70	38	106	73	2	23	0	0	178	134	312	1247
Acanthopagrus butcheri	2	0	1	12	1	1	4	7	8	20	28	37
Girella tricuspidata	0	0	0	0	0	0	0	0	0	0	0	1
Mugil cephalus	0	0	0	0	0	0	0	0	0	0	0	1
Aldrichetta forsteri	15	13	11	17	142	41	61	15	229	86	315	5409
Dotalabrus aurantiacus	0	0	0	0	0	0	0	0	0	0	0	1
Neoodax balteatus	0	0	0	0	7	3	8	1	15	4	19	32
Crapatalus arenarius	20	42	0	0	0	0	0	0	20	42	62	198
Pseudaphritis urvillii	0	0	0	2	0	2	48	51	48	55	103	197
Cristiceps australis	0	0	0	0	3	7	5	9	8	16	24	35
Heteroclinus adelaidae	0	0	0	0	0	0	0	0	0	0	0	1
Pictiblennius tasmanianus	0	0	0	0	2	0	0	0	2	0	2	2
Favonigobius tamarensis	0	0	0	3	26	139	37	46	63	188	251	930
Favonigobius lateralis	0	0	0	0	1	0	0	0	1	0	1	2
Nesogobius hinsbyi	0	0	0	0	1	0	0	0	1	0	1	2
Nesogobius pulchellus	0	0	0	0	3	0	0	0	3	0	3	3
Nesogobius sp.2	0	0	17	7	162	41	0	0	179	48	227	519
Pseudogobius olorum	0	0	0	0	0	1	14	0	14	1	15	126
Tasmanogobius lordi	0	0	0	0	0	0	0	0	0	0	0	2
Tasmanogobius sp.3	0	0	0	0	1	8	0	0	1	8	9	19
Ammotretis rostratus	1	7	48	68	1	0	0	0	50	75	125	677
Ammotretis liturata	4	6	0	0	0	0	0	0	4	6	10	69
Rhombosolea tapirina	0	0	15	16	14	28	3	8	32	52	84	620
Penicipelta vittiger	0	0	0	0	8	11	0	0	8	11	19	25
Acanthaluteres spilomelanurus	0	0	0	0	4	1	3	7	7	8	15	29
Brachaluteres jacksonianus	0	0	0	0	5	3	0	0	5	3	8	20
Meuschenia freycineti	0	0	2	0	11	2	10	7	23	9	32	53
Contusus richei	27	1	1	0	6	0	0	0	34	1	35	61
Contusus sp.	0	0	0	0	0	1	0	0	0	1	1	1

Appendix 6:2 : Similarity matrix (%) for centroid cluster analysis of sampling sites based on the occurrence of species.

1. Nine Mile Beach
2. Nine Mile Beach
3. Point Bagot
4. Sandflat
5. Point Meredith
6. Yellow Sandbanks
7. Barney Wards Bay.

Site 1	-						
" 2	55.6	-					
" 3	27.3	41.7	-				
" 4	17.1	30.6	46.9	-			
" 5	20.0	38.5	44.0	44.1	-		
" 6	20.7	41.4	57.7	63.6	65.4	-	
" 7	17.4	32.0	32.0	35.3	59.1	53.8	-
	1	2	3	4	5	6	7

Appendix 6:3. Food charts for fish species collected in the environs of the Great Swanport Estuary based on the total diets of all individuals sampled. The family order is designated below:

:1 *Engraulis australis, Anguilla australis, Galaxias maculatus, Pseudophycis bachus* .

:2 *Hyporhamphus melanochir, Atherinosoma microstoma, Atherinosoma presbyteroides, Urocampus carinirostris.*

:3 *Syngnathus tuckeri, Stigmatopora nigra, Gymnapistes marmoratus, Scorpaena ergastulorum.*

:4 *Platycephalus bassensis, Sillago bassensis, Caranx georgianus, Arripis trutta.*

:5 *Acanthopagrus butcheri, Aldrichetta forsteri, Neoodax balteatus, Crapatalus arenarius.*

:6 *Pseudaphritis urvillii, Cristiceps australis, Favonigobius tamarensis, Nesogobius sp. 2.*

:7 *Pseudogobius olorum, Tasmanogobius sp.3, Ammotretis rostratus, Ammotretis liturata.*

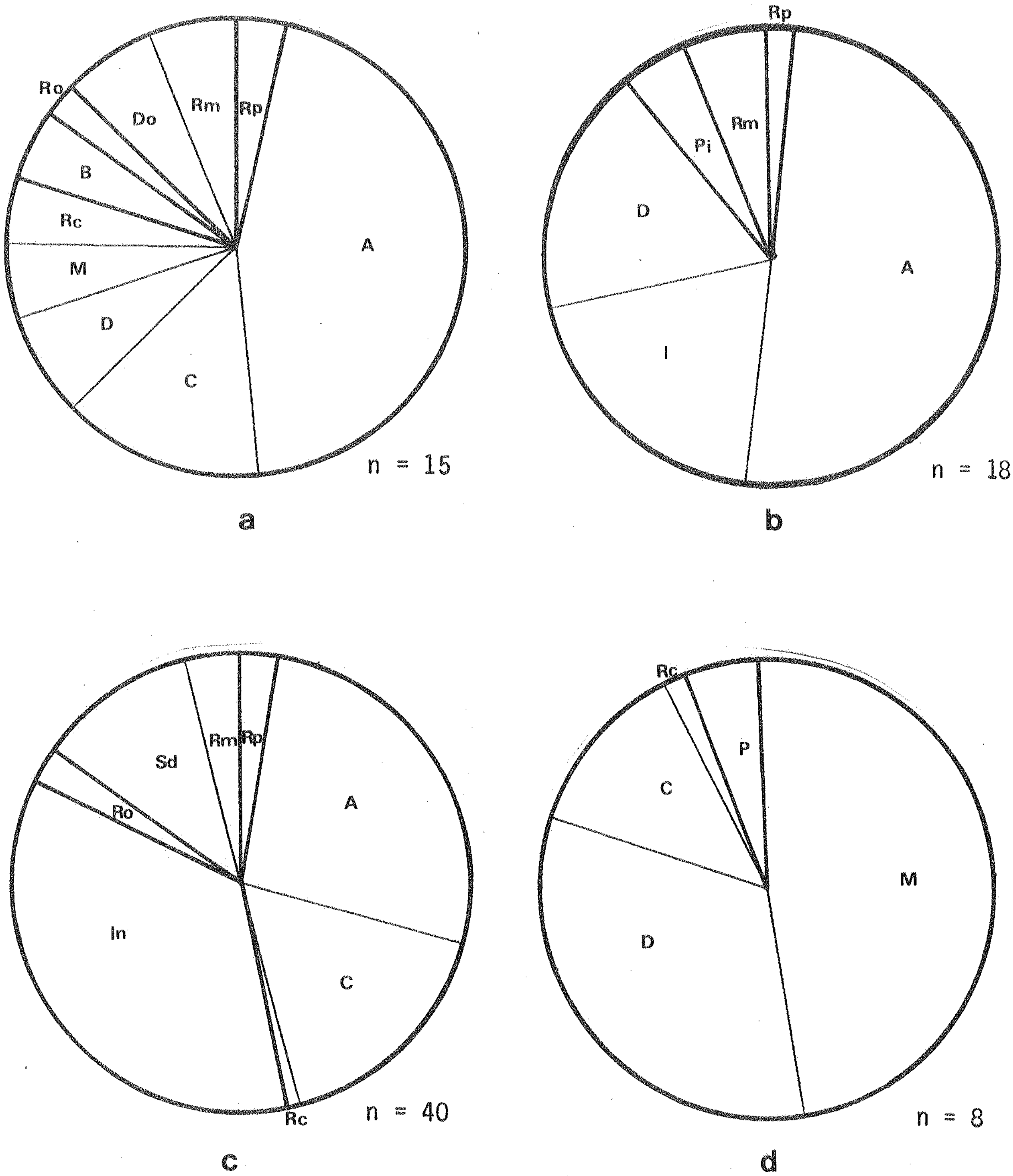
:8 *Rhombosolea tapirina, Penicipelta vittiger, Acanthaluteres spilomelanurus, Brachaluteres jacksonianus.*

:9 *Meuschenia freycineti, Contusus richei.*

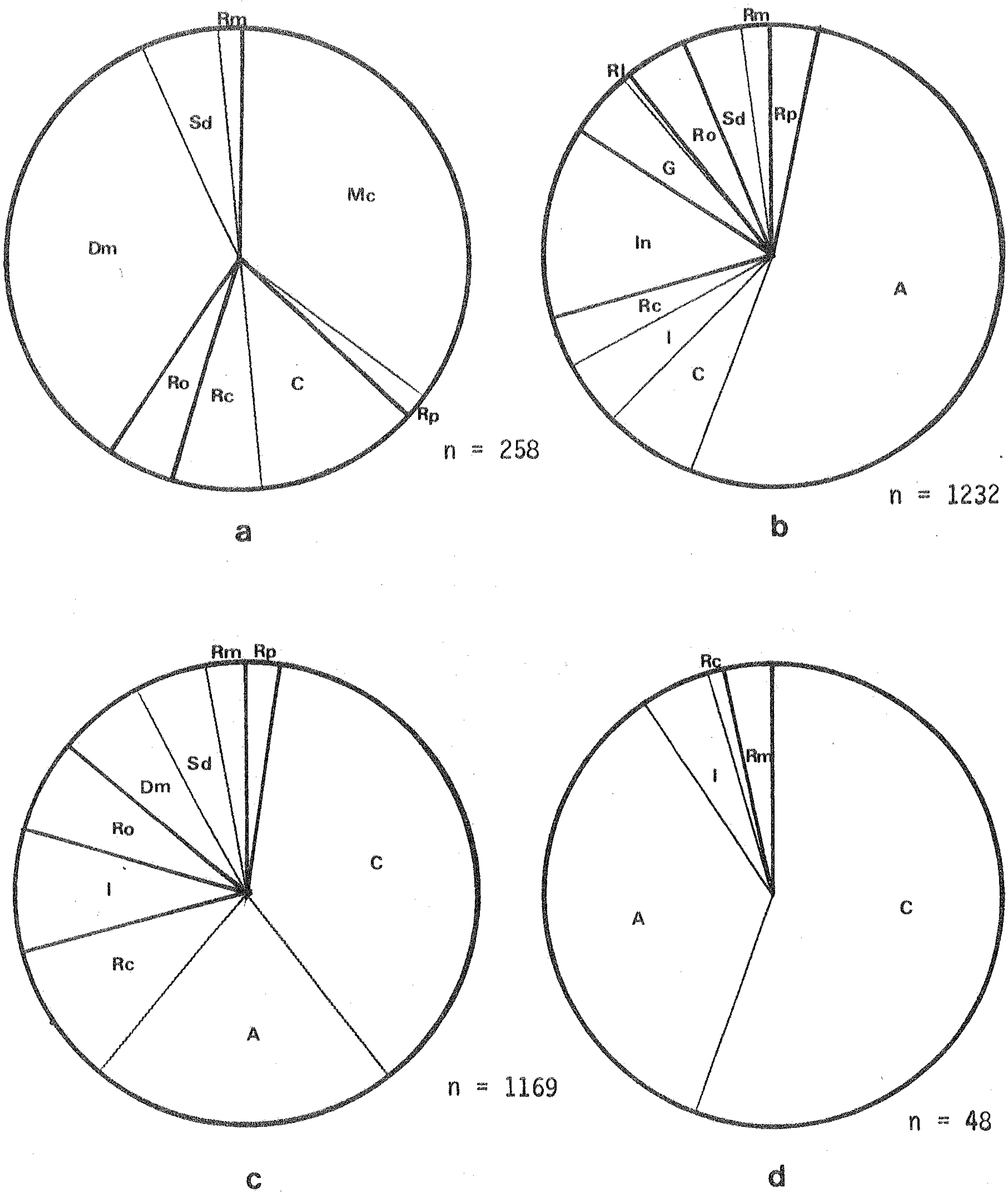
Appendix 6:3.

Key to prey groups in the following food charts.

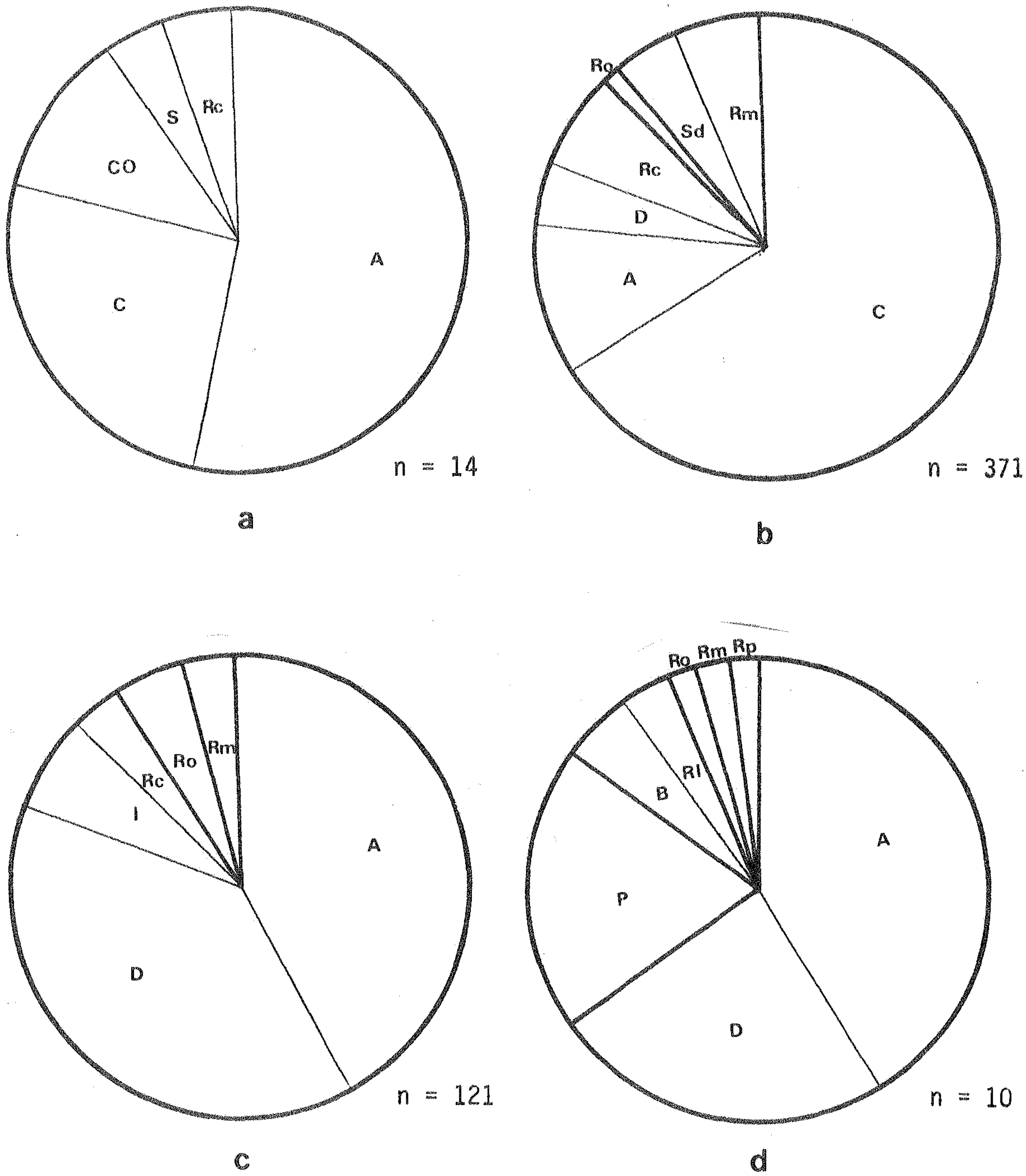
(A)	Amphipoda	(In)	Insecta
(Ar)	Arachnida	(M)	Mysidacea
(As)	Ascidiacea	(Mc)	Seagrasses
(B)	Bivalvia	(O)	Ostracoda
(Br)	Bryozoa	(P)	Polychaeta
(C)	Copepoda	(Pi)	Pisces
(Ch)	Chlorophyta	(Ph)	Phaeophyta
(Ci)	Cirripedia	(Po)	Porifera
(Cl)	Cladocera	(Pr)	Protozoa
(Cn)	Cnidaria	(Ra)	Remainder - polychaeta
(Cu)	Cumacea	(Rc)	Remainder - crustacea
(D)	Decapoda	(Rd)	Rhodophyta
(Dm)	Digested material	(Rl)	Remainder - mollusca
(Do)	Organic detritus	(Rm)	Remainder - miscellaneous
(Ds)	Diatoms/Desmids	(Ro)	Remainder - other animals
(E)	Echiura	(Rp)	Remainder - plants
(Eo)	Echinoidea	(S)	Stomatopoda
(G)	Gastropoda	(Sd)	Sediment
(I)	Isopoda	(T)	Tanaidacea



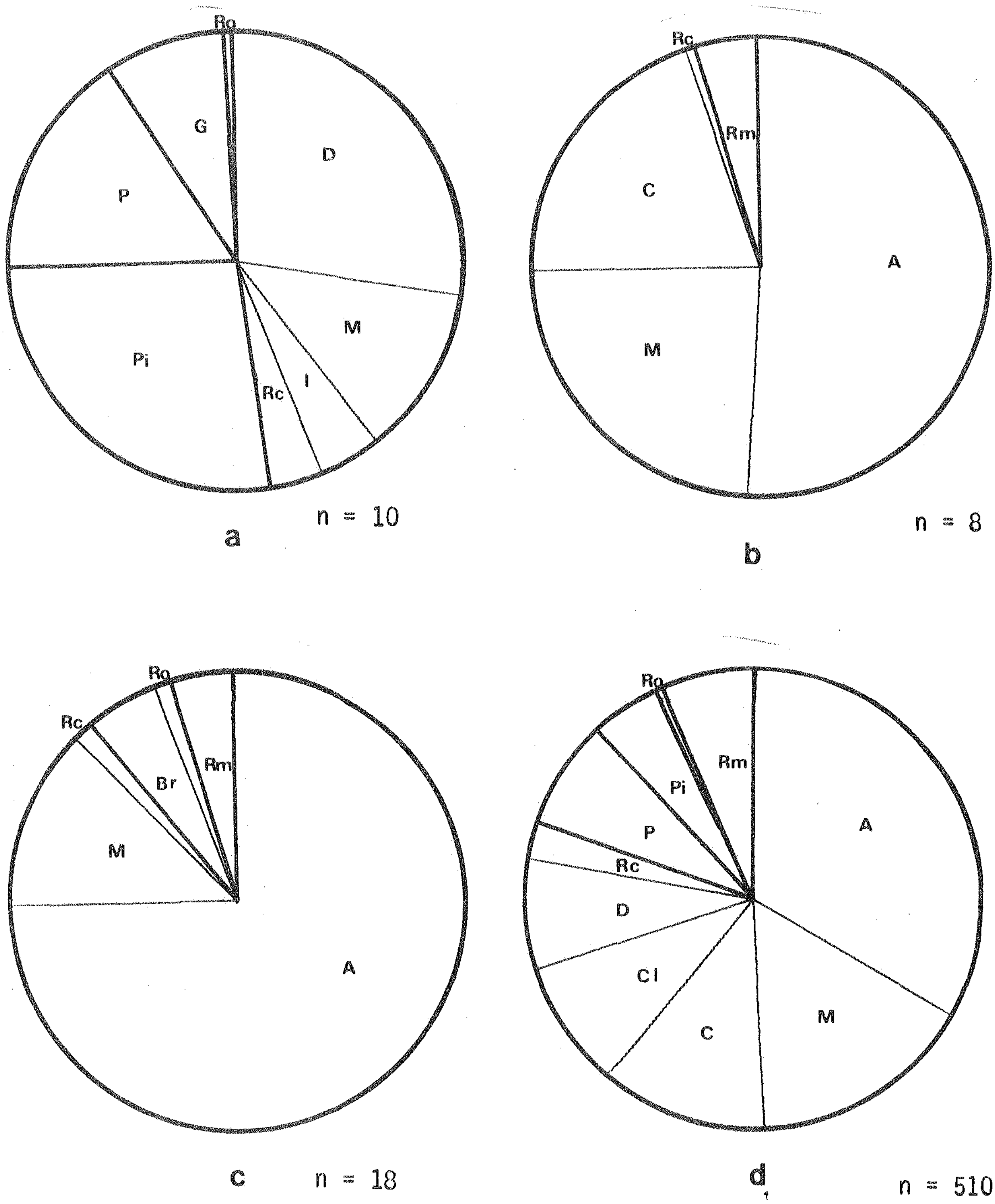
Appendix 6:3:1: Food charts for (a) *Engraulis australis*, (b) *Anguilla australis*, (c) *Galaxias maculatus*, and (d) *Pseudophycis bachus*, based on the total diets of all individuals sampled.



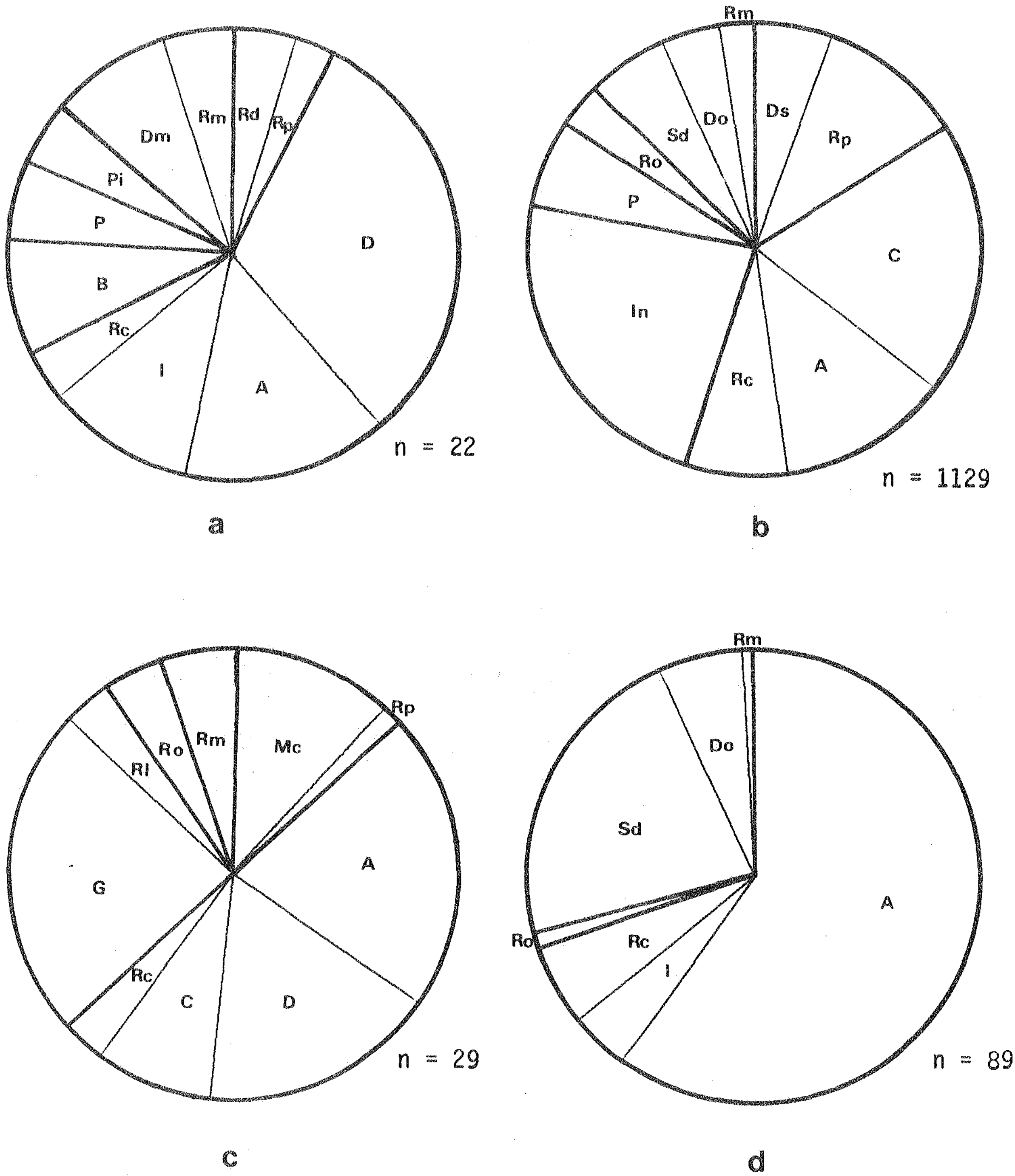
Appendix 6:3:2: Food charts for (a) *Hyporhamphus melanochir*, (b) *Atherinasoma microstoma*, (c) *Atherinasoma presbyteroides* and (d) *Urocampus carinirostris*, based on the total diets of all individuals sampled.



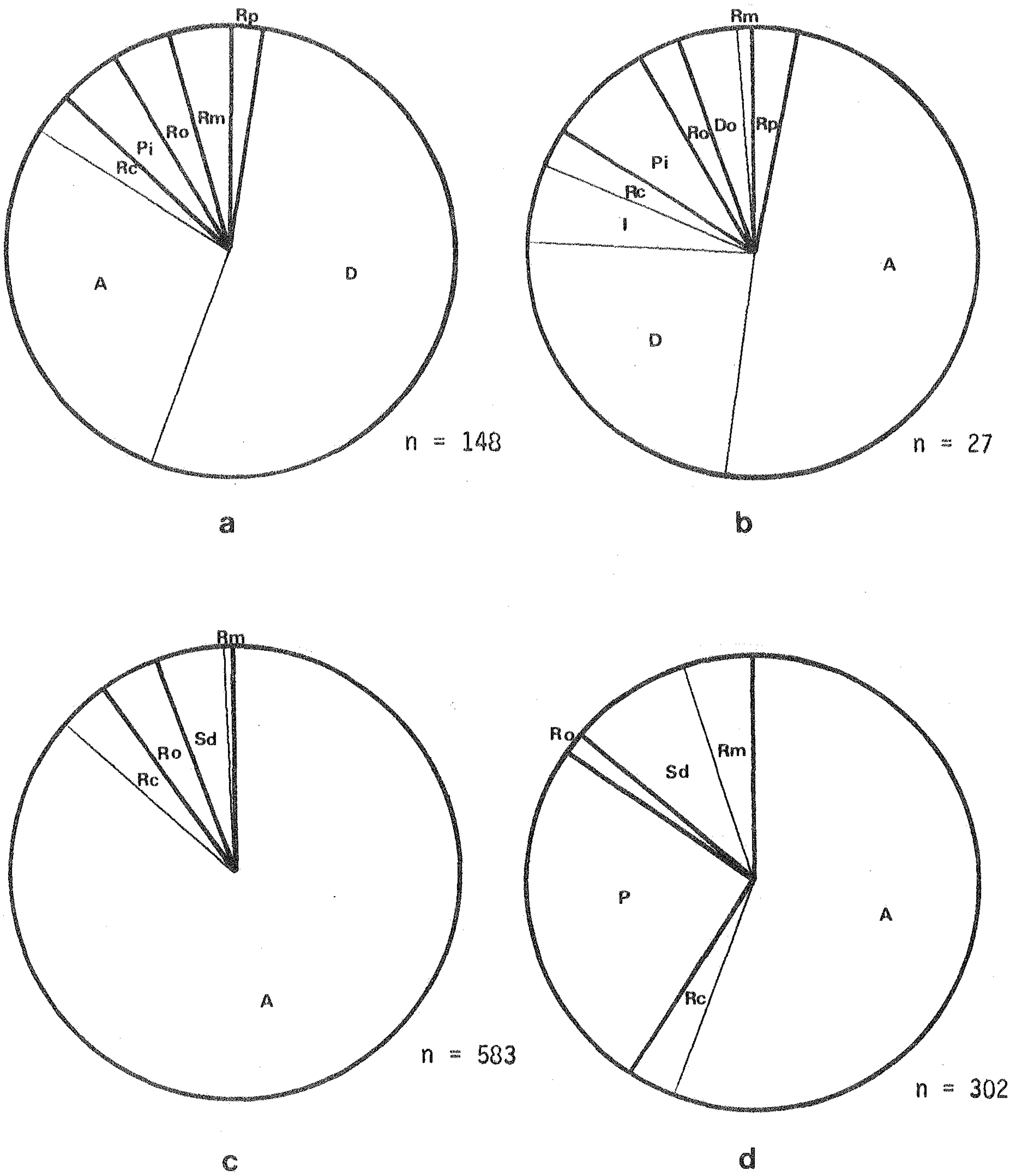
Appendix 6:3:3 : Food charts for (a) *Syngnathus tuckeri*, (b) *Stigmatopora nigra*, (c) *Gymnapistes marmoratus* and (d) *Scorpaena ergastulorum*, based on the total diets of all individuals sampled.



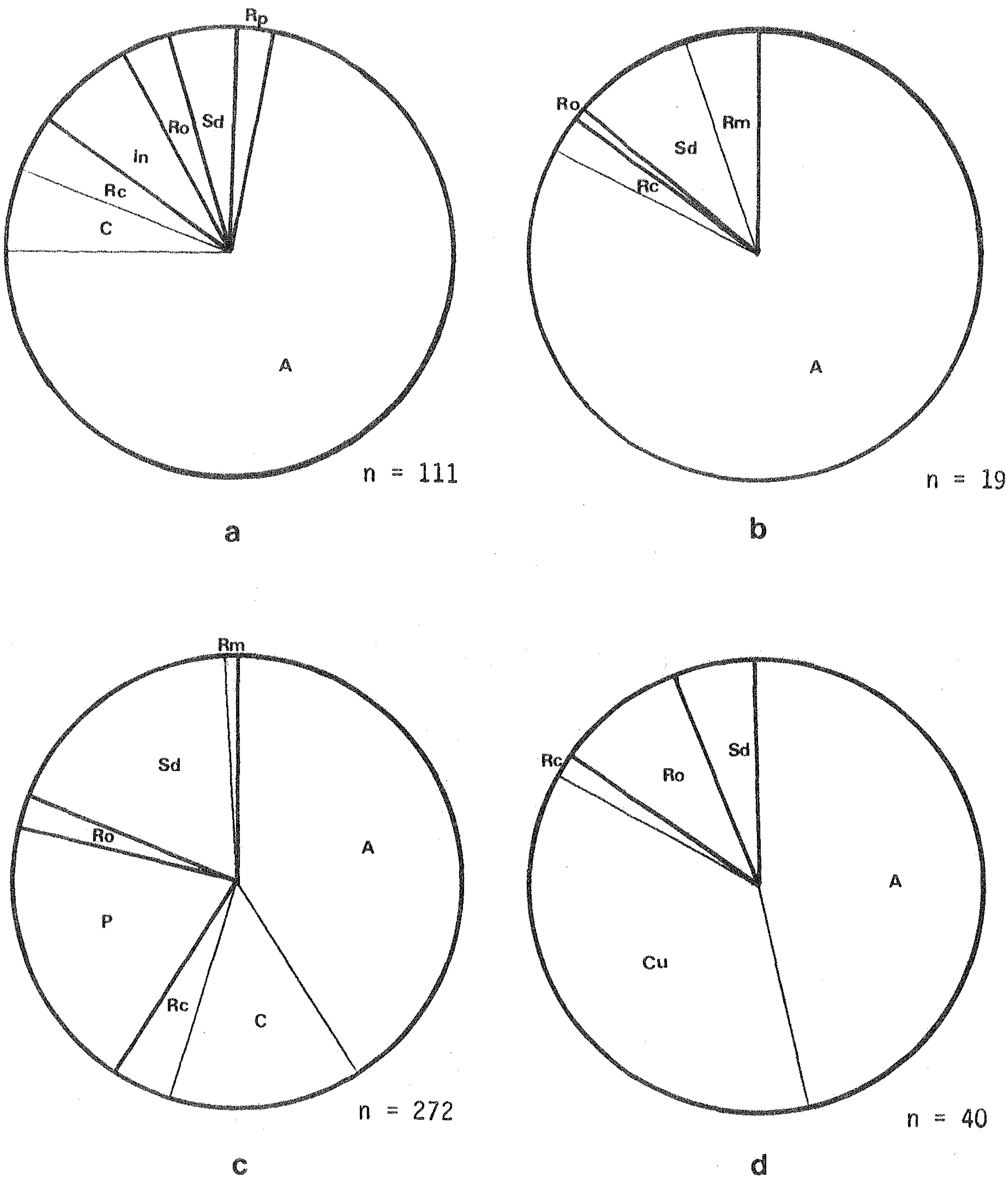
Appendix 6:3:4 : Food charts for (a) *Platycephalus bassensis*, (b) *Sillago bassensis*, (c) *Caranx georgianus* and (d) *Arripis trutta*, based on the total diets of all individuals sampled.



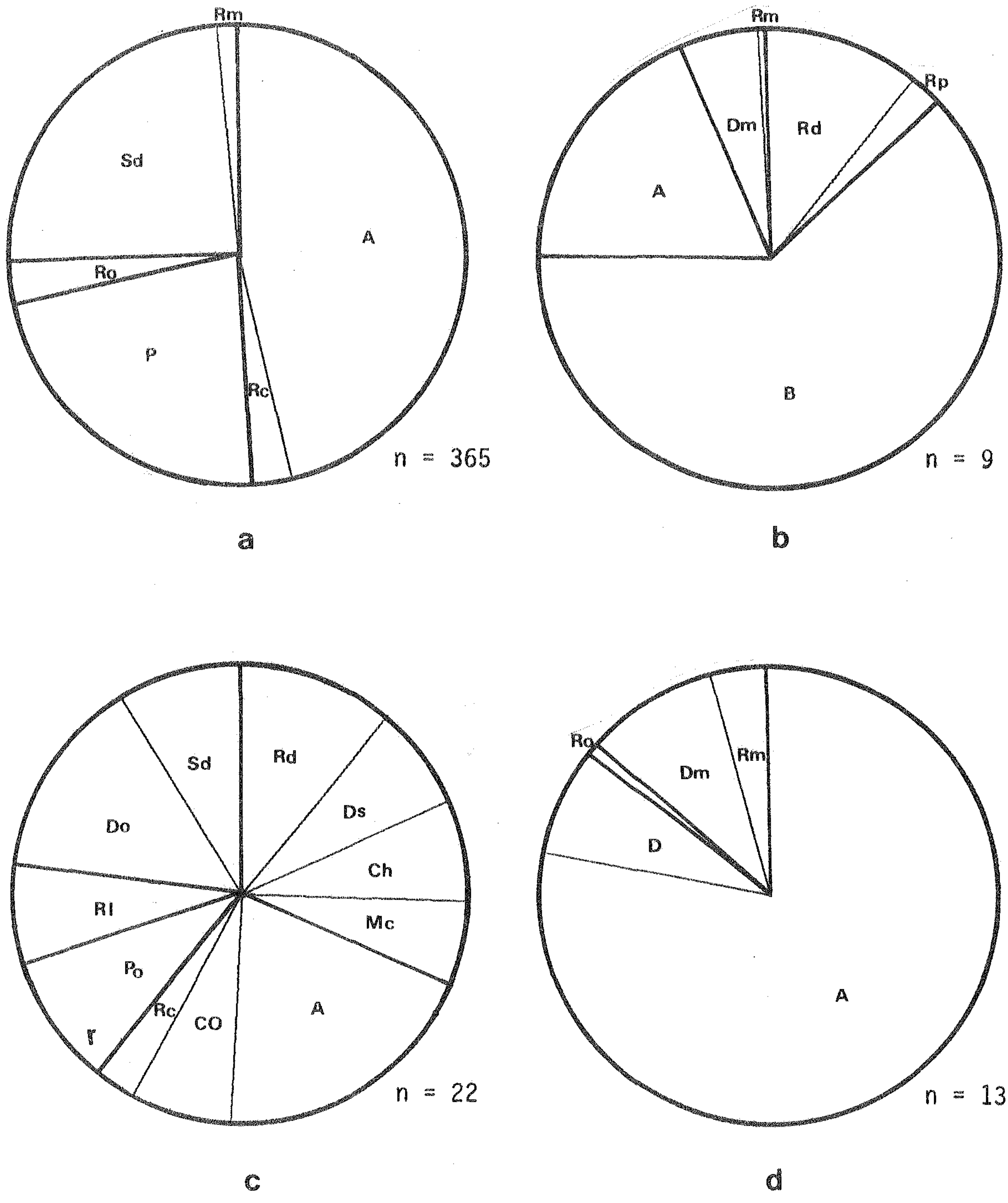
Appendix 6:3:5: Food charts for (a) *Acanthopagrus butcheri*, (b) *Aldrichetta forsteri*, (c) *Neoodax balteatus* and (d) *Crapatalus arenarius*, based on the total diets of all individuals sampled.



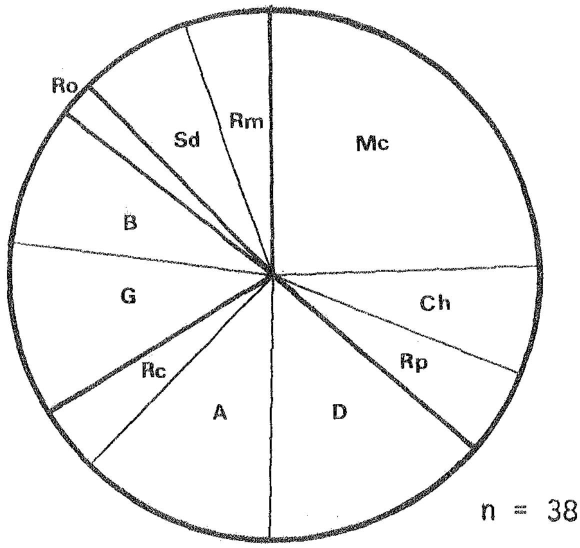
Appendix 6:3:6: Food charts for (a) *Pseudaphritis urvillii*, (b) *Cristiceps australis*, (c) *Favonigobius tamarensis* and (d) *Nesogobius sp.2*, based on the total diets of all individuals sampled.



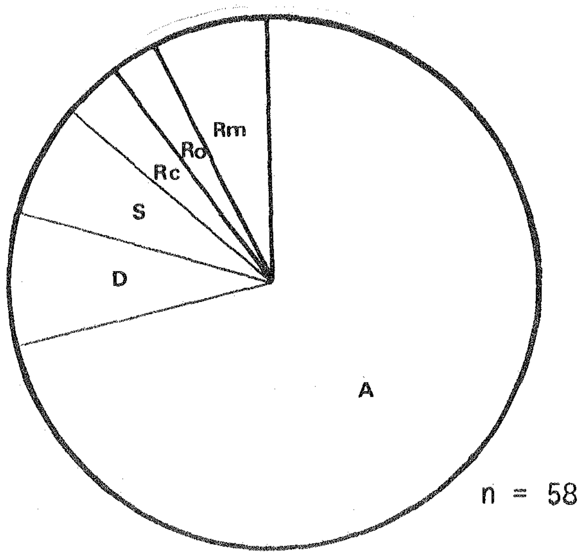
Appendix 6:3:7: Food charts for (a) *Pseudogobius olorum*, (b) *Tasmanogobius sp.3*, (c) *Ammotretis rostratus*, and (d) *Ammotretis liturata*, based on the total diets of all individuals sampled.



Appendix 6:3:8: Food charts for (a) *Rhombosolea tapirina*, (b) *Penicipelta vittiger*, (c) *Acanthaluteres spilomelanurus*, and (d) *Brachaluteres jacksonianus*, based on the total diets of all individuals sampled.



a



b

Appendix 6:3:9: Food charts for (a) *Meuschenia freycineti*, and (b) *Contusus richei*, based on the total diets of all individuals sampled.

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 1 based on (a) prey group and (b) prey species. Ali, *Ammotretis liturata*. Atu, *Arripis trutta*. Afo, *Aldrichetta forsteri*. Car, *Crapatalus arenarius*.

a

1	Ali	-			
2	Atu	29.4	-		
3	Afo	31.6	23.0	-	
4	Car	26.9	17.5	41.6	-
		1	2	3	4

b

1	Ali	-			
2	Car	35.7	-		
3	Afo	7.1	10.7	-	
4	Atu	9.5	17.5	26.1	-
		1	2	3	4

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 2 based on (c) prey group and (d) prey species.
Hme, *Hyporhamphus melanochir*. Aps, *Atherinosoma presbyteroides*. Afo, *Aldrichetta forsteri*. Ali, *Ammotretis liturata*. Atu, *Arripis trutta*. Sni, *Stigmatopora nigra*. Car, *Crapatalus arenarius*.

c

1	Hme	-						
2	Aps	51.8	-					
3	Afo	44.3	45.8	-				
4	Ali	36.4	45.9	39.0	-			
5	Atu	42.0	47.2	43.6	61.9	-		
6	Sni	47.1	56.5	44.9	61.1	59.5	-	
7	Car	40.7	38.9	36.4	43.5	52.7	50.6	-
		1	2	3	4	5	6	7

d

1	Hme	-						
2	Aps	35.0	-					
3	Ali	3.3	7.7	-				
4	Sni	14.3	10.5	19.0	-			
5	Afo	17.3	18.4	19.2	14.6	-		
6	Atu	17.9	14.5	15.5	13.2	42.6	-	
7	Cri	22.6	9.4	18.2	28.0	30.2	39.6	-
		1	2	3	4	5	6	7

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 3 based on (e) prey group and (f) prey species.
Hme, *Hyporhamphus melanochir*. Aps, *Atherinosoma presbyteroides*. Atu, *Arripis trutta*. Rta, *Rhombosolea tapirina*. Aro, *Ammotretis rostratus*. Nsp, *Nesogobius* sp. 2. Ami, *Atherinosoma microstoma*. Afo, *Aldrichetta forsteri*.

e

1	Hme	-							
2	Aps	53.6	-						
3	Aro	46.7	56.2	-					
4	Rta	44.0	46.6	73.7	-				
5	Atu	44.2	55.2	67.0	60.9	-			
6	Nsp	47.9	56.6	57.8	66.0	51.4	-		
7	Ami	38.6	43.8	52.7	63.9	49.7	45.0	-	
8	Afo	41.8	53.0	49.6	57.7	48.7	47.6	49.9	-
		1	2	3	4	5	6	7	8

f

1	Hme	-							
2	Aro	14.8	-						
3	Rta	14.3	38.5	-					
4	Nsp	8.9	40.4	47.5	-				
5	Atu	17.2	37.3	39.3	36.2	-			
6	Afo	20.0	35.2	34.4	36.1	36.0	-		
7	Ami	17.1	38.5	38.1	37.2	32.2	43.9	-	
8	Aps	20.0	37.1	30.2	29.7	34.2	41.3	30.2	-
		1	2	3	4	5	6	7	8

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 4 based on (g) prey group and (h) prey species.

Gma, *Galaxias maculatus*. Hme, *Hyporhamphus melanochir*. Aro, *Ammotretis rostratus*.
Fta, *Favonigobius tamarensis*. Rta, *Rhombosolea tapirina*. Nsp, *Nesogobius* sp. 2.
Sni, *Stigmatopora nigra*. Ami, *Atherinosoma microstoma*. Aps, *Atherinosoma presbyteroides*.
Gmr, *Gymnapistes marmoratus*. Afo, *Aldrichetta forsteri*.

g

1	Gma	-										
2	Hme	49.3	-									
3	Aro	45.1	59.8	-								
4	Fta	56.2	68.7	77.7	-							
5	Rta	63.2	63.1	77.9	75.7	-						
6	Nsp	54.0	65.1	75.8	78.6	79.9	-					
7	Sni	51.8	60.9	54.7	72.8	59.9	61.2	-				
8	Ami	47.7	52.9	59.2	58.9	56.7	64.3	54.4	-			
9	Aps	60.6	63.0	61.3	62.9	58.4	65.1	68.6	76.4	-		
10	Gmr	37.5	49.9	59.2	64.7	57.8	66.3	56.9	58.2	56.6	-	
11	Afo	44.4	41.2	44.5	49.2	45.6	51.8	53.2	47.0	52.1	42.3	-
		1	2	3	4	5	6	7	8	9	10	11

h

1	Gma	-										
2	Sni	24.0	-									
3	Hme	17.7	18.8	-								
4	Aro	8.3	13.2	10.0	-							
5	Rta	2.5	9.4	14.3	29.3	-						
6	Nsp	7.3	13.0	15.9	19.1	44.9	-					
7	Fta	9.1	18.2	14.6	25.0	41.5	44.4	-				
8	Afo	9.7	26.3	17.8	16.7	23.3	29.8	31.4	-			
9	Ami	13.6	28.8	21.3	21.6	30.5	35.6	37.7	38.6	-		
10	Aps	13.0	27.9	13.3	21.7	25.7	33.8	33.8	41.6	44.8	-	
11	Gmr	4.5	11.1	15.4	6.1	28.2	20.5	21.3	12.8	15.7	14.8	-
		1	2	3	4	5	6	7	8	9	10	11

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 5 based on (i) prey group and (j) prey species.
Rta, *Rhombosolea tapirina*. Fta, *Favonigobius tamarensis*.
Ami, *Atherinosoma microstoma*. Hme, *Hyporhamphus melanochir*.
Aps, *Atherinosoma presbyteroides*. Afo, *Aldrichetta forsteri*.

i

1	Rta	-					
2	Fta	69.7	-				
3	Ami	57.9	60.3	-			
4	Hme	60.9	57.3	52.1	-		
5	Aps	42.7	50.7	48.5	39.4	-	
6	Afo	26.4	35.8	28.7	26.3	38.0	-
		1	2	3	4	5	6

j

1	Hme	-					
2	Rta	14.3	-				
3	Fta	10.5	65.0	-			
4	Afo	2.6	30.8	33.3	-		
5	Ami	5.3	33.3	42.5	50.0	-	
6	Aps	5.3	26.8	35.7	50.0	61.7	-
		1	2	3	4	5	6

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 6 based on (k) prey group and (l) prey species.
Gma, *Galaxias maculatus*. Rta, *Rhombosolea tapirina*. Ami, *Atherinosoma microstoma*.
Fta, *Favonigobius tamarensis*. Pol, *Pseudogobius olorum*. Sni, *Stigmatopora nigra*.
Gmr, *Gymnapistes marmoratus*. Uca, *Urocampus carinirostris*. Aps, *Atherinosoma presbyteroides*.
Pur, *Pseudaphritis urvillii*. Afo, *Aldrichetta forsteri*. Nba, *Neodax balteatus*.
Mfr, *Meuschenia freycineti*.

k

1	Gma	-												
2	Rta	75.2	-											
3	Ami	78.7	78.9	-										
4	Fta	77.6	79.5	81.6	-									
5	Pol	58.9	59.6	76.5	74.6	-								
6	Sni	57.7	55.7	70.9	65.7	49.2	-							
7	Gmr	63.7	60.9	74.7	74.0	65.1	74.0	-						
8	Uca	66.5	63.4	80.2	73.7	63.8	73.6	73.5	-					
9	Aps	65.4	63.0	70.8	65.3	62.4	70.6	62.8	74.3	-				
10	Pur	64.9	62.0	68.1	72.5	59.3	64.8	70.1	65.9	59.3	-			
11	Afo	63.5	60.6	60.6	60.4	62.9	57.8	55.1	60.3	59.2	55.8	-		
12	Nba	52.4	51.7	61.3	59.7	42.4	51.8	59.2	55.5	61.7	52.9	50.7	-	
13	Mfr	56.9	59.3	63.4	63.1	56.8	57.9	61.6	60.0	61.8	57.6	63.8	67.6	-
		1	2	3	4	5	6	7	8	9	10	11	12	13

l

1	Gma	-												
2	Pol	66.7	-											
3	Uca	45.0	38.1	-										
4	Sni	27.6	27.6	38.5	-									
5	Afo	28.0	28.0	23.5	26.8	-								
6	Ami	25.0	27.3	21.1	24.2	44.4	-							
7	Aps	32.6	32.6	30.4	28.3	55.7	60.3	-						
8	Gmr	39.3	39.3	26.7	21.1	37.7	31.7	40.0	-					
9	Pur	35.5	44.8	28.1	28.9	43.4	41.4	43.1	50.0	-				
10	Fta	20.0	27.3	20.6	19.5	31.0	32.3	28.1	45.7	45.9	-			
11	Nba	24.0	29.2	36.4	18.8	27.5	22.4	26.5	21.2	43.3	26.5	-		
12	Mfr	21.4	21.4	26.9	24.2	25.9	23.3	27.5	30.3	39.4	24.3	34.6	-	
13	Rta	18.2	30.0	19.0	13.8	20.0	20.0	18.8	25.0	31.0	15.2	8.0	15.4	-
		1	2	3	4	5	6	7	8	9	10	11	12	13

Appendix 6:4 (continued) : Similarity matrices (%) for centroid cluster analysis of the diets of major species at sampling site 7 based on (m) prey group and (n) prey species.

Afo, *Aldrichetta forsteri*. Ami, *Atherinosoma microstoma*. Fta, *Favonigobius tamarensis*. Pol, *Pseudogobius olorum*. Gmr, *Gymnapistes marmoratus*. Pur, *Pseudaphritis urvillii*. Aps, *Atherinosoma presbyteroides*.

m

1	Afo	-						
2	Ami	47.2	-					
3	Fta	42.1	66.5	-				
4	Pol	47.4	70.7	80.0	-			
5	Gmr	33.4	55.2	61.1	63.5	-		
6	Pur	44.5	58.4	66.6	66.0	76.6	-	
7	Aps	41.8	43.8	43.5	48.1	38.9	49.0	-
		1	2	3	4	5	6	7

n

1	Afo	-						
2	Ami	48.3	-					
3	Aps	25.5	32.7	-				
4	Pur	28.3	27.8	27.3	-			
5	Pol	29.2	38.5	32.4	36.4	-		
6	Fta	20.5	26.0	28.6	33.3	34.5	-	
7	Gmr	11.9	11.8	11.1	20.0	13.8	33.3	-
		1	2	3	4	5	6	7

Appendix 6:5 : Similarity matrix (%) for centroid cluster analysis of fish guilds for sites 1 - 7 and seasons (U, summer. P, spring. W, winter. A, autumn).
Grazers - based on (a) prey group and (b) prey species.
Aro, *Ammotretis rostratus*. Rta, *Rhombosolea tapirina*. Ali, *Ammotretis liturata*.

a

1	Aro 3 (P)	-										
2	Aro 4 (U)	65.3	-									
3	Rta 5 (P)	72.6	73.2	-								
4	Rta 5 (U)	69.6	71.4	81.0	-							
5	Aro 3 (U)	59.4	53.2	57.9	51.1	-						
6	Aro 3 (A)	45.6	55.2	61.5	53.0	67.1	-					
7	Rta 3 (U)	49.8	63.0	71.4	60.8	66.5	76.8	-				
8	Rta 5 (A)	50.2	51.6	61.4	62.0	43.6	44.5	53.3	-			
9	Rta 4 (U)	47.3	63.0	53.0	57.1	39.9	40.1	45.7	49.5	-		
10	Ali 2 (U)	53.8	51.3	57.8	52.2	41.8	28.3	43.8	35.0	43.3	-	
11	Rta 3 (P)	43.5	51.4	54.1	46.0	52.2	30.6	46.0	33.7	37.4	31.2	-
		1	2	3	4	5	6	7	8	9	10	11

b

1	Aro 3 (P)	-										
2	Aro 3 (U)	38.5	-									
3	Aro 3 (A)	22.7	37.5	-								
4	Rta 3 (P)	25.0	28.6	42.1	-							
5	Rta 3 (U)	22.7	13.8	14.3	22.7	-						
6	Ali 2 (U)	19.0	14.8	10.0	13.6	4.8	-					
7	Aro 4 (U)	14.8	19.4	12.0	6.9	7.7	0.0	-				
8	Rta 4 (P)	7.1	5.9	8.0	11.1	12.5	0.0	29.2	-			
9	Rta 6 (P)	13.0	10.3	4.5	4.0	4.5	0.0	35.0	36.8	-		
10	Rta 5 (U)	9.1	7.1	5.0	4.3	5.0	0.0	31.6	33.3	81.8	-	
11	Rta 5 (A)	13.6	10.7	4.8	4.2	4.8	0.0	23.8	31.6	50.0	35.7	-
		1	2	3	4	5	6	7	8	9	10	11

Appendix 6:5 : Similarity matrix (%) for centroid cluster analysis of fish guilds for sites 1 - 7 and seasons (U, summer. P, spring. W, winter. A, autumn).
Browsers -based on (c) prey group and (d) prey species.
Fta, *Favonigobius tamarensis*. Nsp, *Nesogobius* sp. 2. Pol, *Pseudogobius olorum*.

c

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Fta 4 (P)	-																	
2	Fta 4 (U)	63.5	-																
3	Nsp 4 (W)	56.9	94.0	-															
4	Fta 5 (U)	60.7	89.8	91.7	-														
5	Fta 4 (A)	57.2	88.1	88.9	89.6	-													
6	Nsp 4 (U)	59.4	85.8	82.2	80.6	78.3	-												
7	Fta 5 (P)	55.6	83.3	78.2	78.8	74.9	77.2	-											
8	Fta 5 (A)	50.2	87.0	77.6	78.7	71.0	79.8	74.6	-										
9	Pol 6 (U)	47.6	83.3	71.2	73.5	65.9	77.8	71.2	91.4	-									
10	Nsp 4 (P)	50.1	74.4	71.4	70.8	67.1	76.1	67.6	65.2	63.6	-								
11	Nsp 4 (A)	49.4	75.7	67.7	71.7	64.7	80.3	66.4	61.2	61.7	67.8	-							
12	Fta 6 (P)	60.4	72.0	69.7	70.0	71.6	69.1	68.4	61.6	61.1	63.5	64.5	-						
13	Fta 6 (U)	56.3	78.9	79.4	84.3	79.7	75.5	71.7	71.3	68.1	66.3	62.6	84.3	-					
14	Fta 6 (A)	48.8	67.1	62.4	65.3	61.1	64.9	53.8	54.4	51.5	65.0	53.1	72.4	77.9	-				
15	Pol 7 (P)	51.3	62.9	53.0	55.0	54.6	61.4	50.8	41.8	42.2	62.7	51.8	61.8	56.6	41.0	-			
16	Nsp 3 (P)	37.1	59.3	52.8	53.9	47.5	68.6	62.7	48.6	46.5	53.5	61.9	50.9	52.0	43.1	40.3	-		
17	Pol 7 (U)	38.3	51.3	41.0	46.3	43.3	51.5	49.5	37.0	37.3	48.2	42.4	47.4	46.6	34.9	34.3	39.8	-	
18	Nsp 3 (U)	30.9	46.0	40.0	51.1	39.7	56.8	43.6	29.6	27.0	51.1	40.6	44.8	47.6	37.2	32.5	36.7	29.1	-

d

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Fta 4 (P)	-																	
2	Nsp 4 (P)	48.0	-																
3	Nsp 3 (P)	21.4	29.6	-															
4	Nsp 3 (U)	8.7	18.2	15.0	-														
5	Fta 4 (U)	23.1	32.0	11.1	5.0	-													
6	Fta 5 (P)	23.1	17.9	7.1	5.0	47.4	-												
7	Fta 5 (U)	16.0	15.4	8.0	5.9	38.9	47.1	-											
8	Fta 5 (A)	13.6	13.0	4.5	7.7	40.0	40.0	50.0	-										
9	Nsp 4 (U)	16.7	20.0	10.0	4.3	34.8	34.8	33.3	26.3	-									
10	Fta 4 (A)	15.4	29.2	16.7	18.8	36.8	23.8	27.8	26.7	26.1	-								
11	Nsp 4 (W)	19.0	30.0	9.5	16.7	40.0	31.3	28.6	40.0	26.3	46.2	-							
12	Nsp 4 (A)	22.7	27.3	13.6	23.1	35.3	27.8	25.0	33.3	23.8	31.3	45.5	-						
13	Fta 6 (P)	19.2	18.5	7.4	11.1	28.6	28.6	50.0	33.3	25.0	25.0	25.0	29.4	-					
14	Fta 6 (U)	13.8	9.7	6.9	10.0	26.1	31.8	30.0	37.5	18.5	17.4	22.2	20.0	55.6	-				
15	Fta 6 (A)	10.0	6.3	6.9	10.0	26.1	31.8	30.0	29.4	18.5	12.5	15.8	14.3	40.0	50.0	-			
16	Pol 6 (U)	9.7	9.4	10.3	4.5	25.0	42.9	28.6	27.8	13.8	16.7	15.0	13.6	31.8	34.8	34.8	-		
17	Pol 7 (P)	4.8	4.5	5.3	10.0	20.0	20.0	25.0	37.5	10.5	14.3	22.2	18.2	30.8	26.7	26.7	25.0	-	
18	Pol 7 (U)	11.1	6.9	3.7	5.6	18.2	30.0	35.3	35.7	11.5	14.3	11.8	10.5	25.0	22.7	22.7	33.3	23.1	-

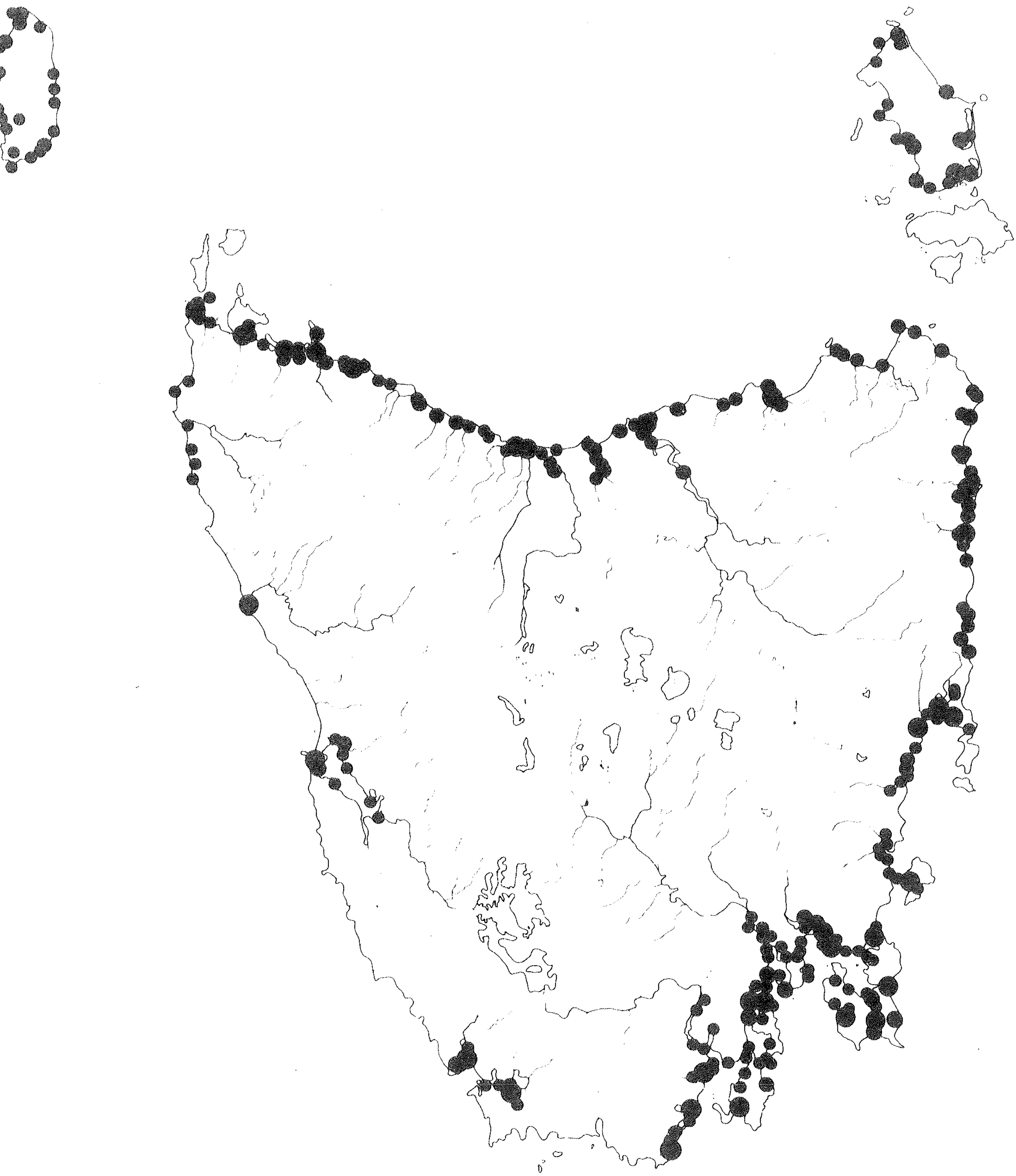
APPENDIX

TO CHAPTER 7

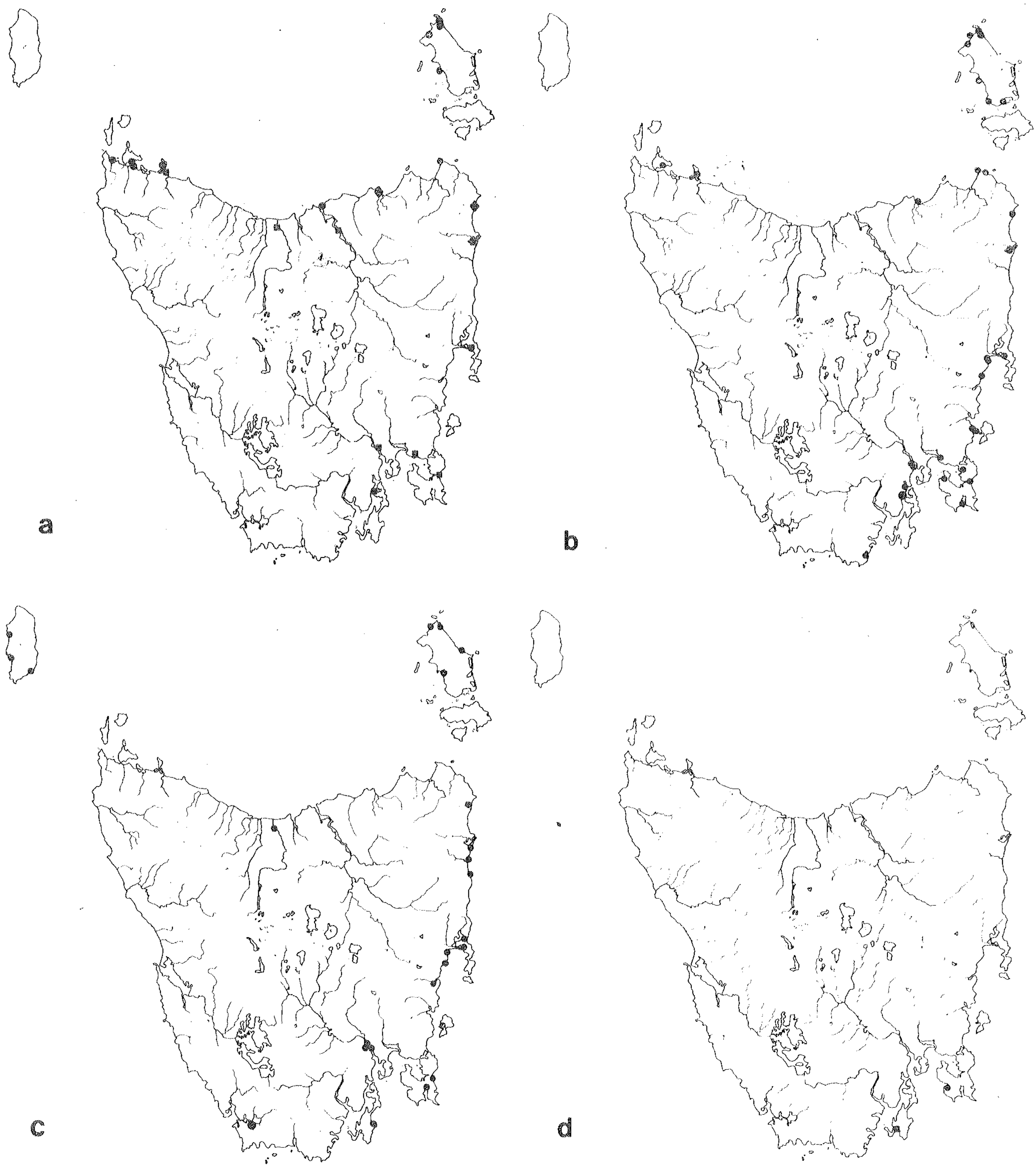
Appendix 7:1 Distributions of fish species collected during sampling programme for Chapter 4. The family order is designated below:

:0	All sampling sites.
:1	Dussumieriidae, Engraulidae, Hemiramphidae, Anguillidae, Gobiesocidae.
:2	Aplochitonidae, Prototroctidae, Retropinnidae, Galaxiidae
:3	Pleuronectidae, Bothidae
:4	Syngnathidae
:5	Syngnathidae, Centrolophidae, Ophidiidae, Blenniidae
:6	Mugilidae, Carangidae, Pomatomidae
:7	Atherinidae
:8	Platycephalidae, Triglidae, Scorpaenidae
:9	Mullidae, Enoplosidae, Sillaginidae, Apogonidae
:10	Sparidae, Kyphosidae, Scorpidae, Kuhliidae, Arripidae, Brachionichthyidae
:11	Leptoscopidae, Uranoscopidae, Bovichthyidae, Eleotridae
:12	Gobiidae
:13	Gobiidae
:14	Clinidae
:15	Labridae, Odacidae, Tetraodontidae
:16	Ostraciontidae, Diodontidae, Monacanthidae.

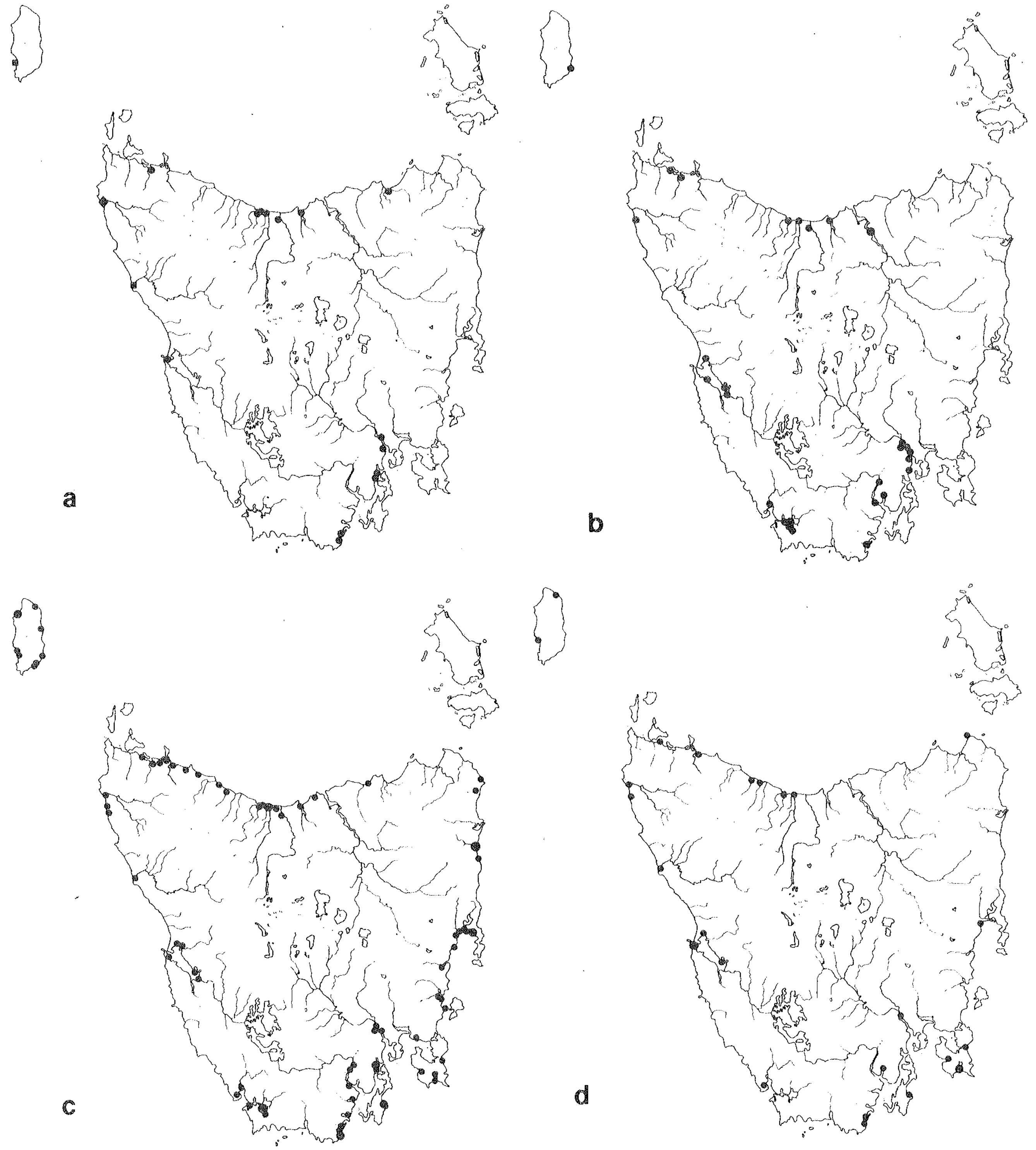
Keys to species are provided with each map. Larger symbols of a type represent several records from that area.



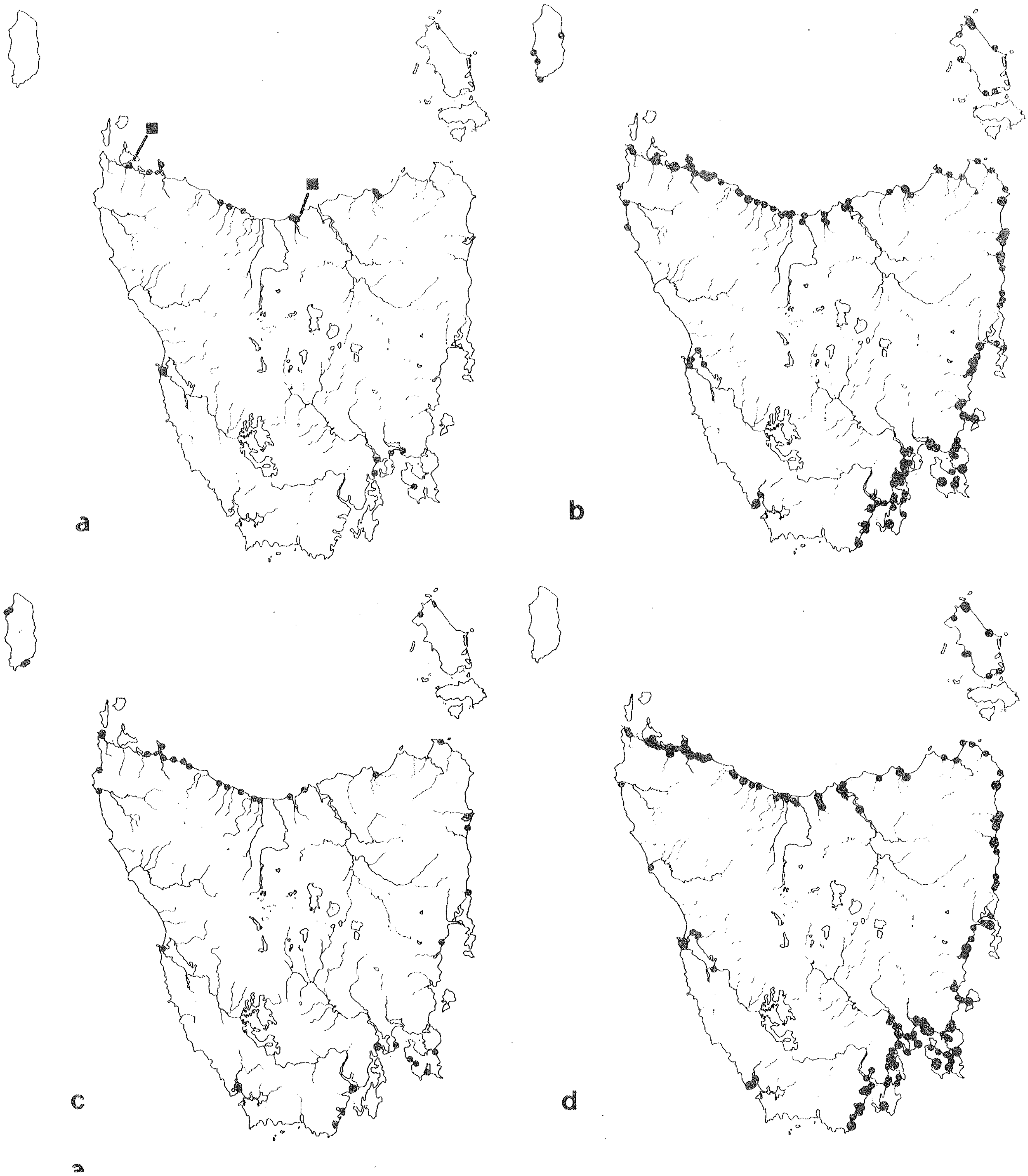
7:1:0 Distribution of sampling sites around Tasmania. Small dots represent a single site; medium dots, 2 overlapping sites; large dots, more than 2 overlapping sites.



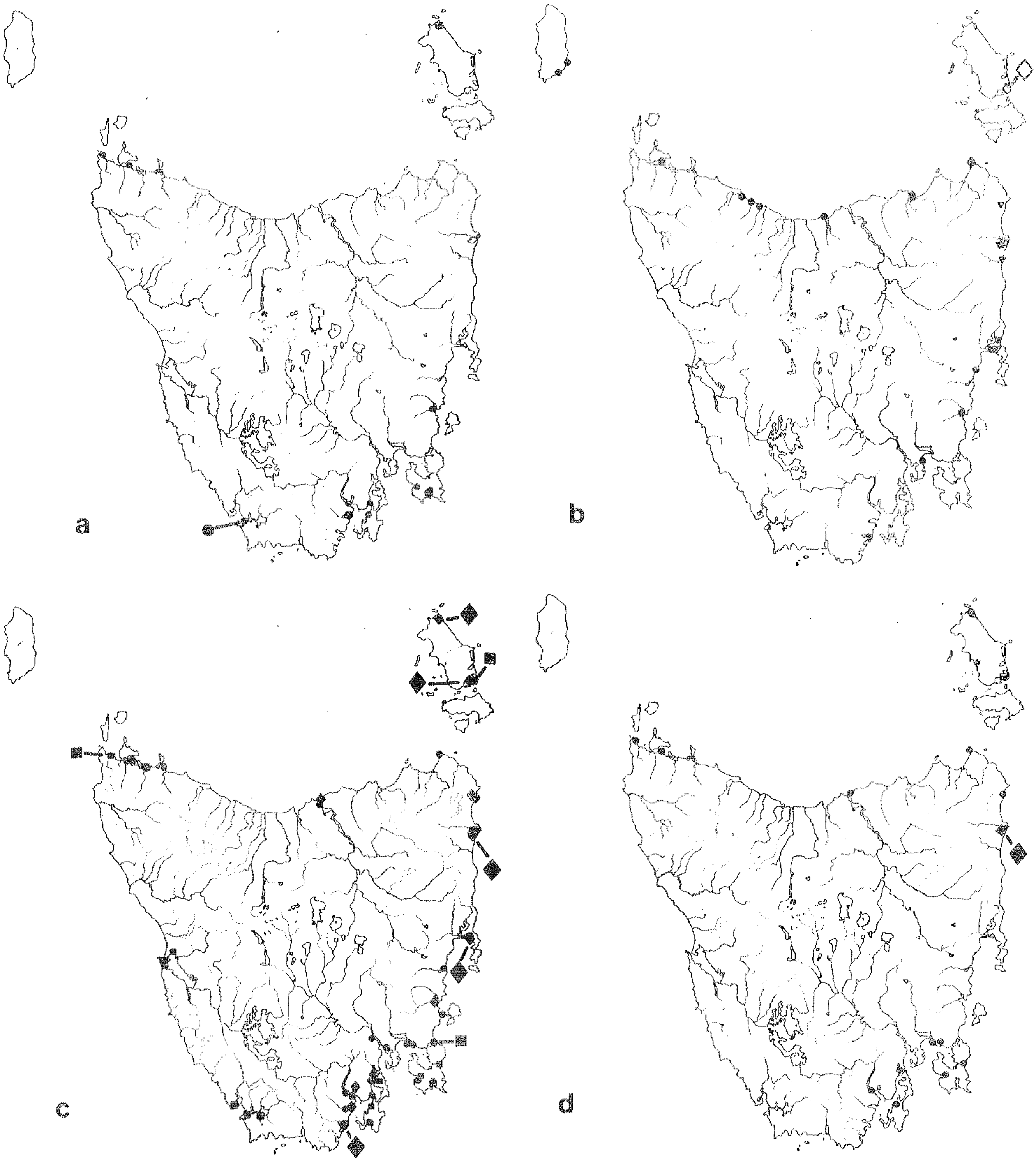
7:1:1. Distributions of (a) *Spratelloides robustus* (●) and *Engraulis australis* (■) (overlap ◆); (b) *Hyporhamphus melanochir* (●); (c) *Anguilla australis* (●); (d) *Alabes parvulus* (●) and *A. rufus* (■).



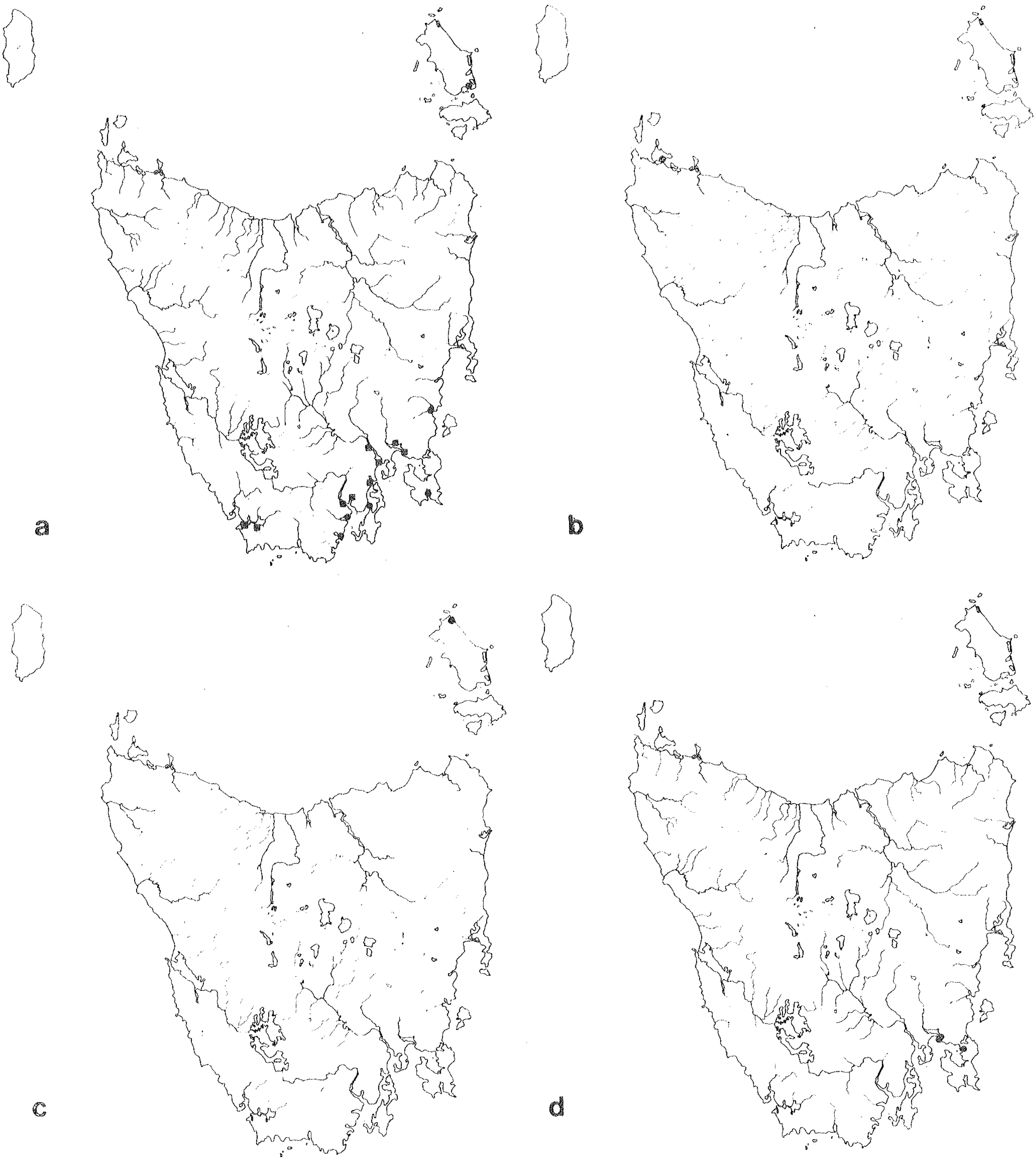
7:1:2. Distributions of (a) *Lovettia sealii* (●) and *Prototroctes maraena* (■) (overlap, ◆); (b) *Retropinna tasmanica* (●); (c) *Galaxias maculatus* (●); (d) *G. truttaceus* (●).



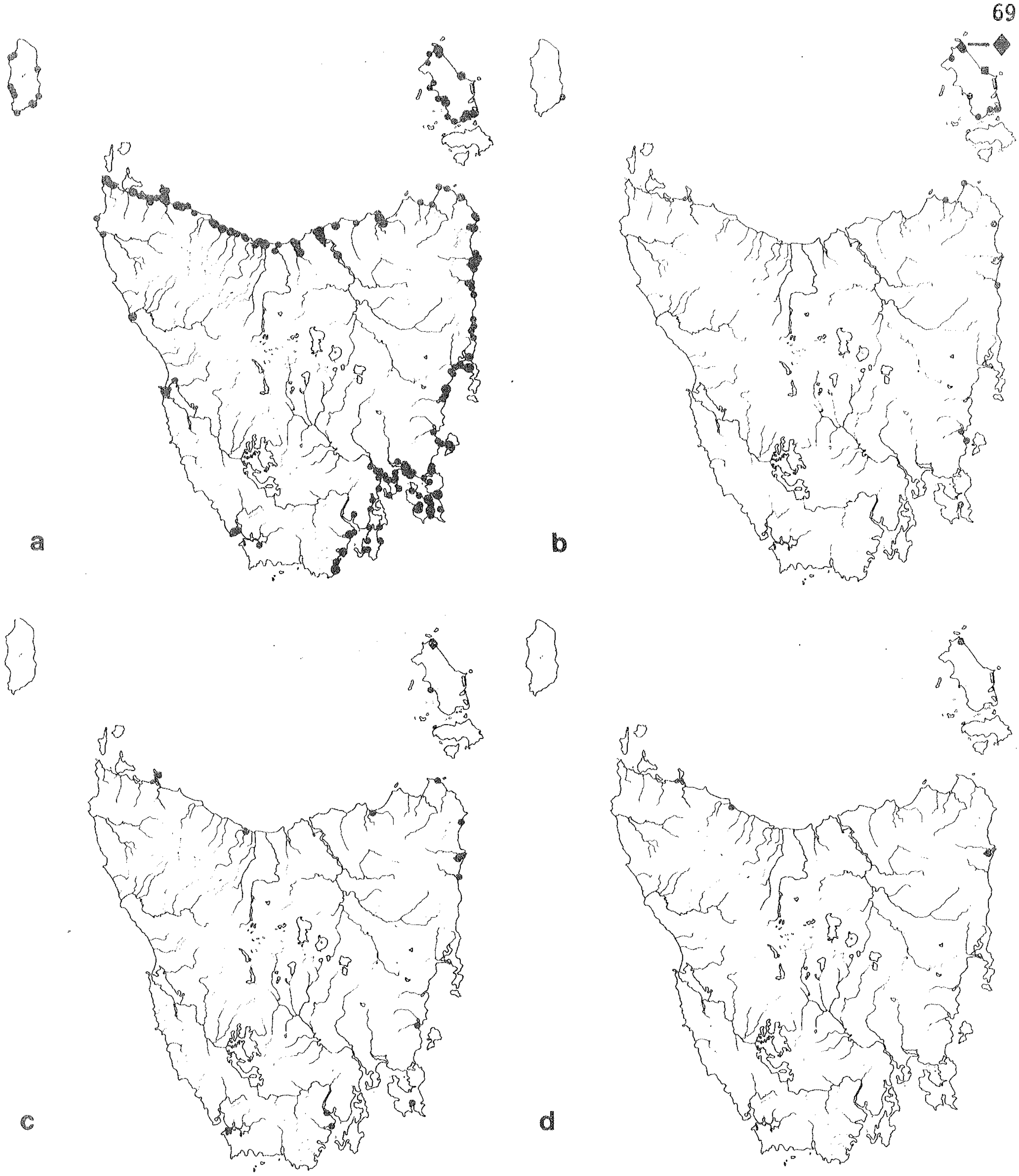
7:1:3. Distributions of (a) *Taratretis derwentensis* (●) and *Arnoglossus bassensis* (■); (b) *Ammotretis rostratus* (●); (c) *A. liturata* (●); (d) *Rhombosolea tapirina* (●).



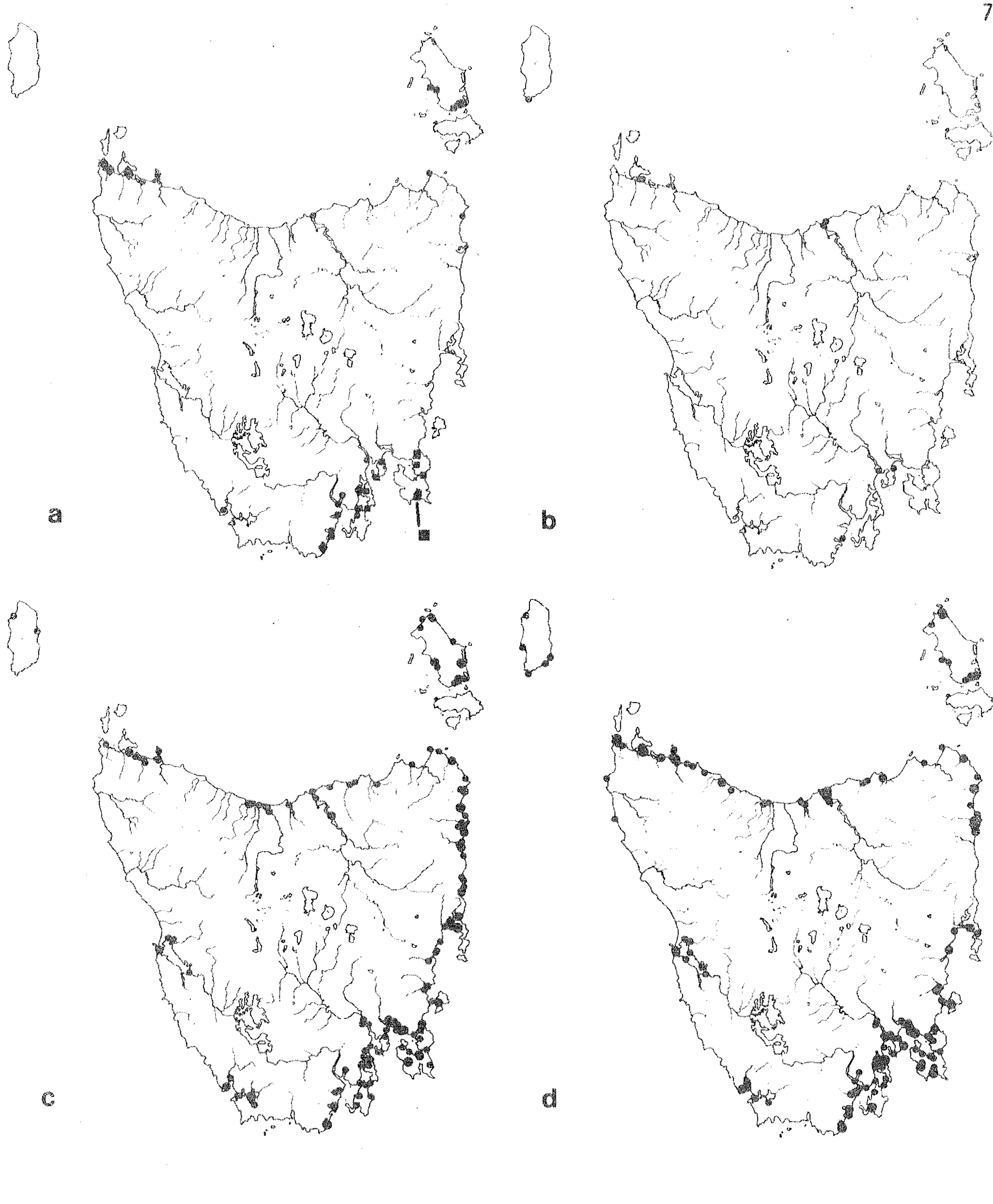
7:1:4. Distributions of (a) *Leptonotus semistriatus* (●) and *L. costatus* (■); (b) *Syngnathus tuckeri* (●), *Lissocampus runa* (■), *Hypselognathus rostratus* (◆), *Urocampus carinirostris* (▼) and *Leptoichthys fistularius* (◇); (c) *Stigmatopora nigra* (●) and *S. argus* (■) (overlap, ◆); (d) *Syngnathus phillipi* (●), *S. poecilolaemus* (■), and *S. curtirostris* (▼) (overlap between *S. phillipi* and *S. poecilolaemus*, ◆).



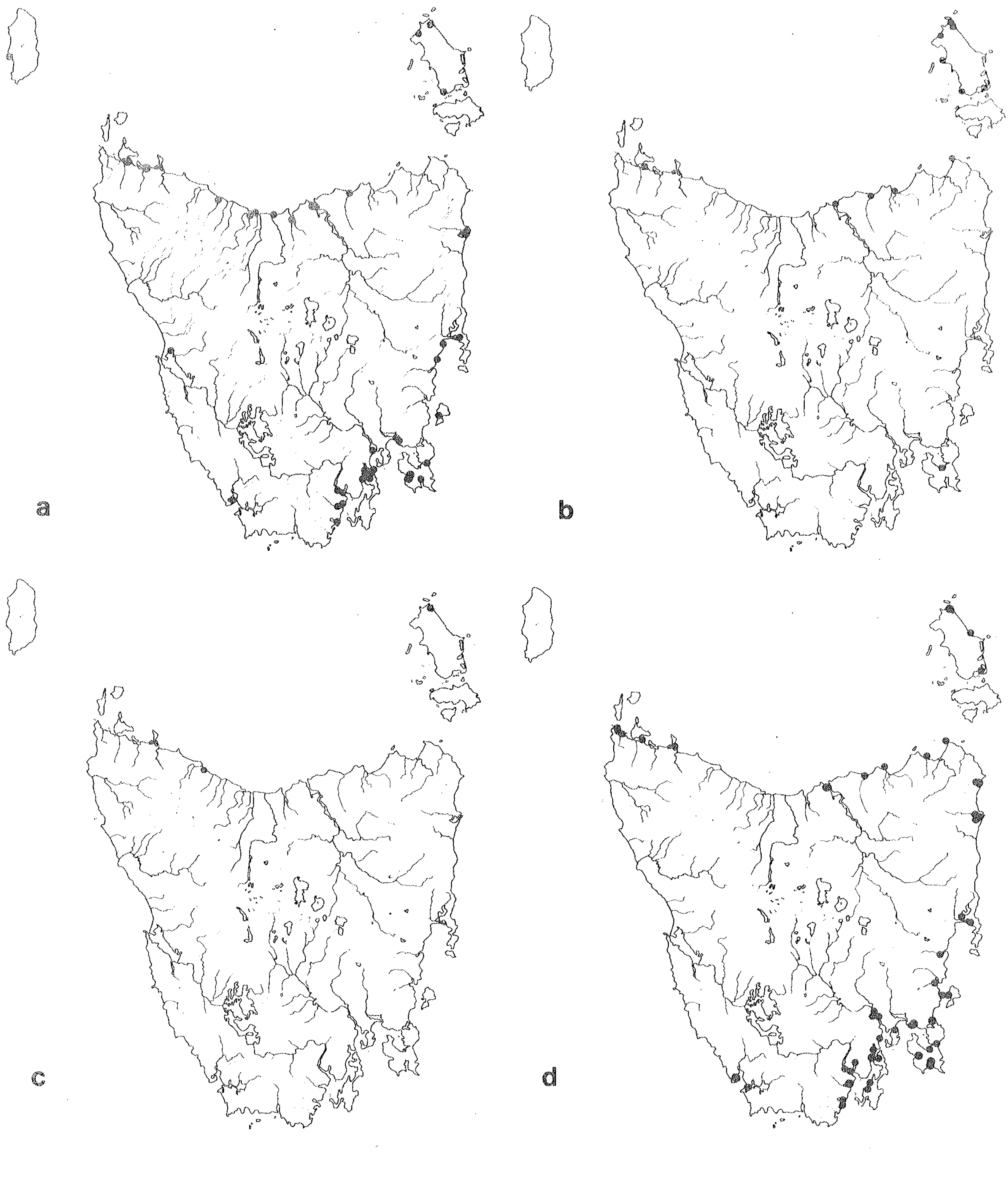
7:1:5. Distributions of (a) *Hippocampus breviceps* (●) and *H. abdominalis* (■); (b) *Seriollela brama* (●); (c) *Genypterus sp.* (●); (d) *Pictiblennius tasmanianus* (●).



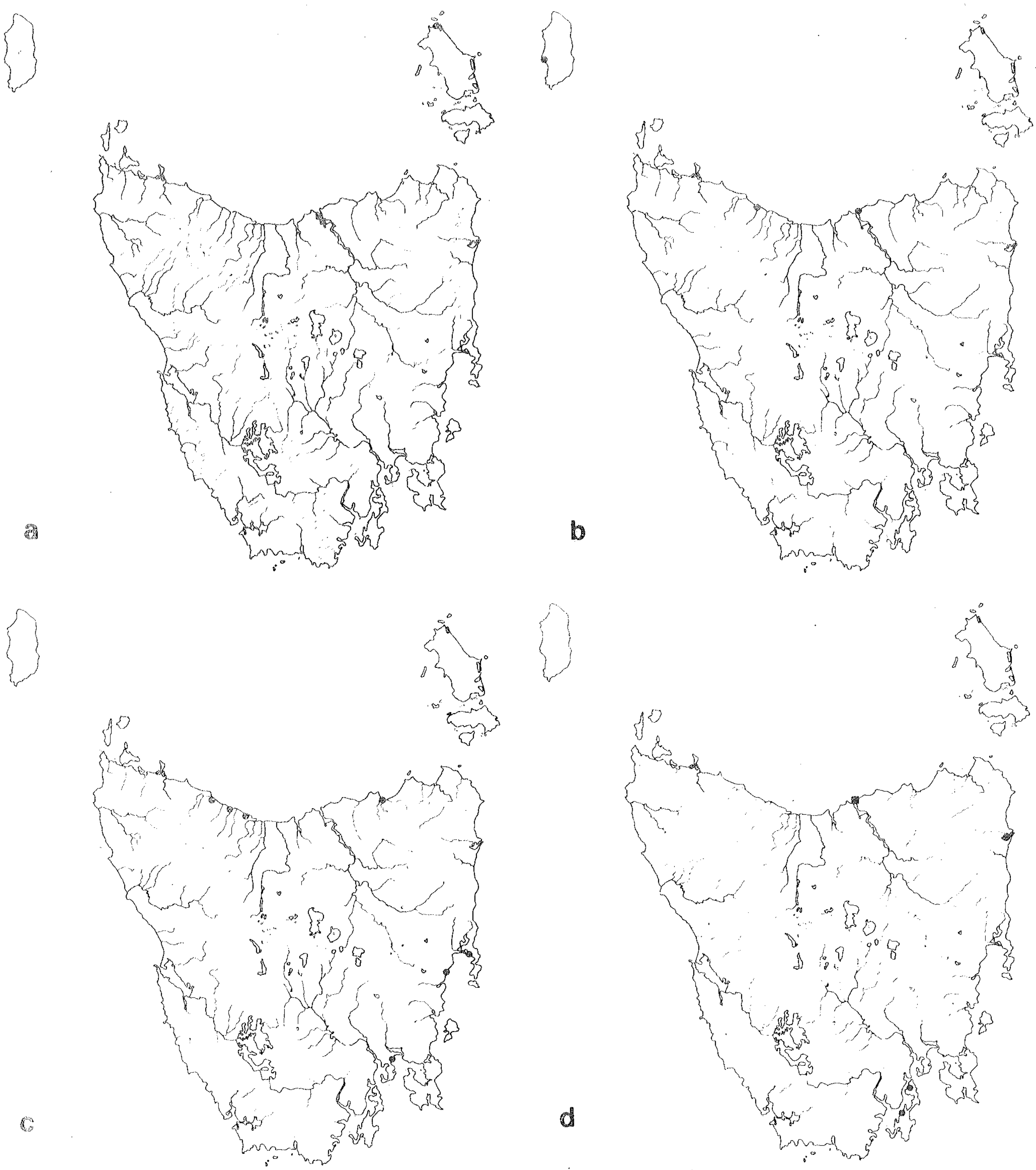
7:1:6. Distributions of (a) *Aldrichetta forsteri* (●); (b) *Myxus elongatus* (●) and *Mugil cephalus* (■) (overlap, ◆); (c) *Caranx georgianus* (●) and *Trachurus declivis* (■) (overlap, ◆); (d) *Pomatomus saltator* (●).



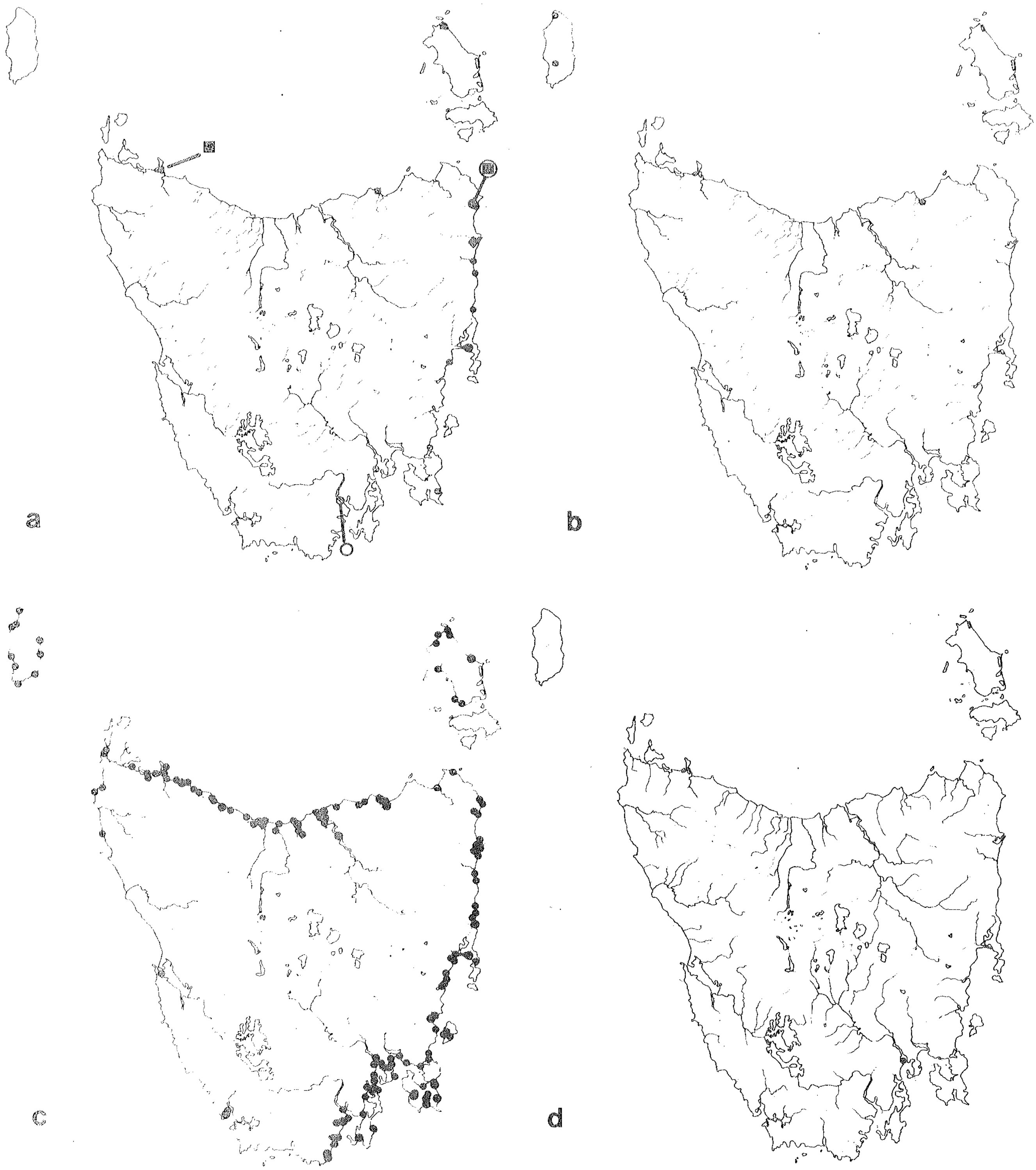
7:1:7. Distributions of (a) *Atherinason sp.* (●) and *A. esox* (■) (overlap, ◆); (b) *A. hepsetoides* (●); (c) *Atherinasoma microstoma* (●); (d) *A. presbyteroides* (●).



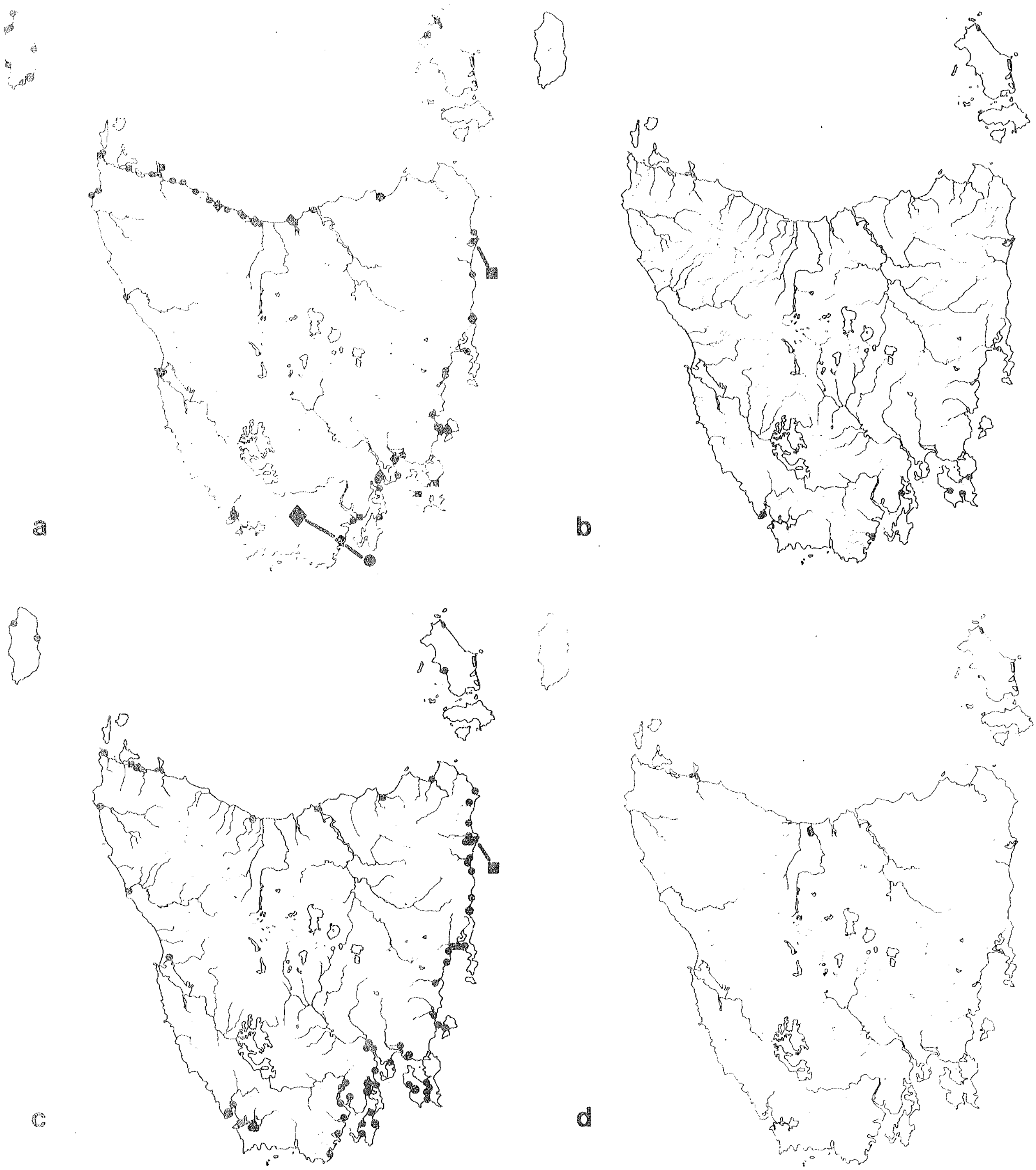
7:1:8. Distributions of (a) *Platycephalus bassensis* (●); (b) *P. castelnaui* (●) and *P. laevigatus* (■); (c) *Chelidonichthys kumu* (●); (d) *Gymnapistes marmoratus* (●).



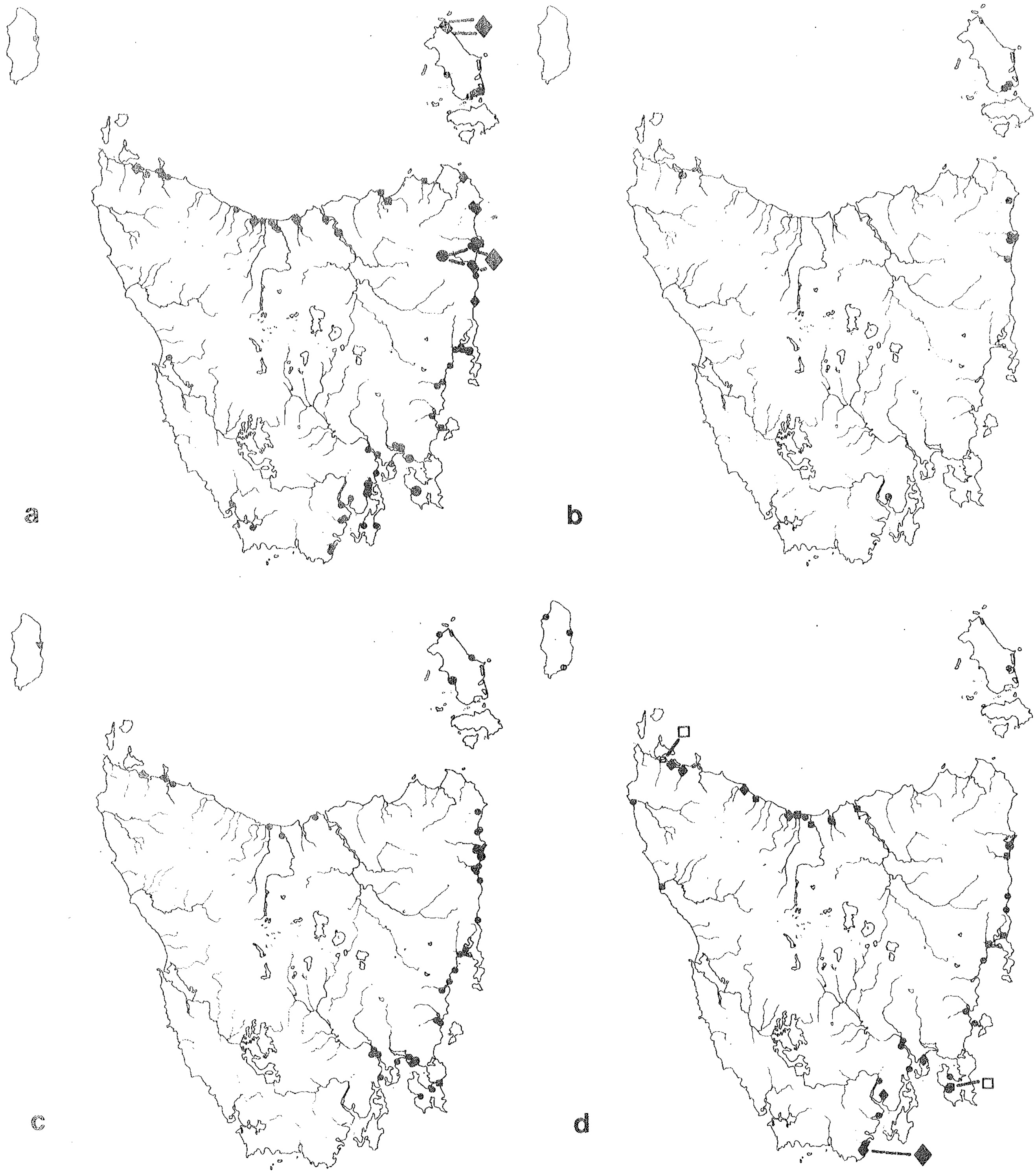
7:1:9. Distributions of (a) *Upeneus tragula* (●) and *Upeneichthys lineatus* (■); (b) *Enoplosus armatus* (●); (c) *Sillago bassensis* (●); (d) *Vincentia conspersus* (●) and *Siphamia cephalotes* (■).



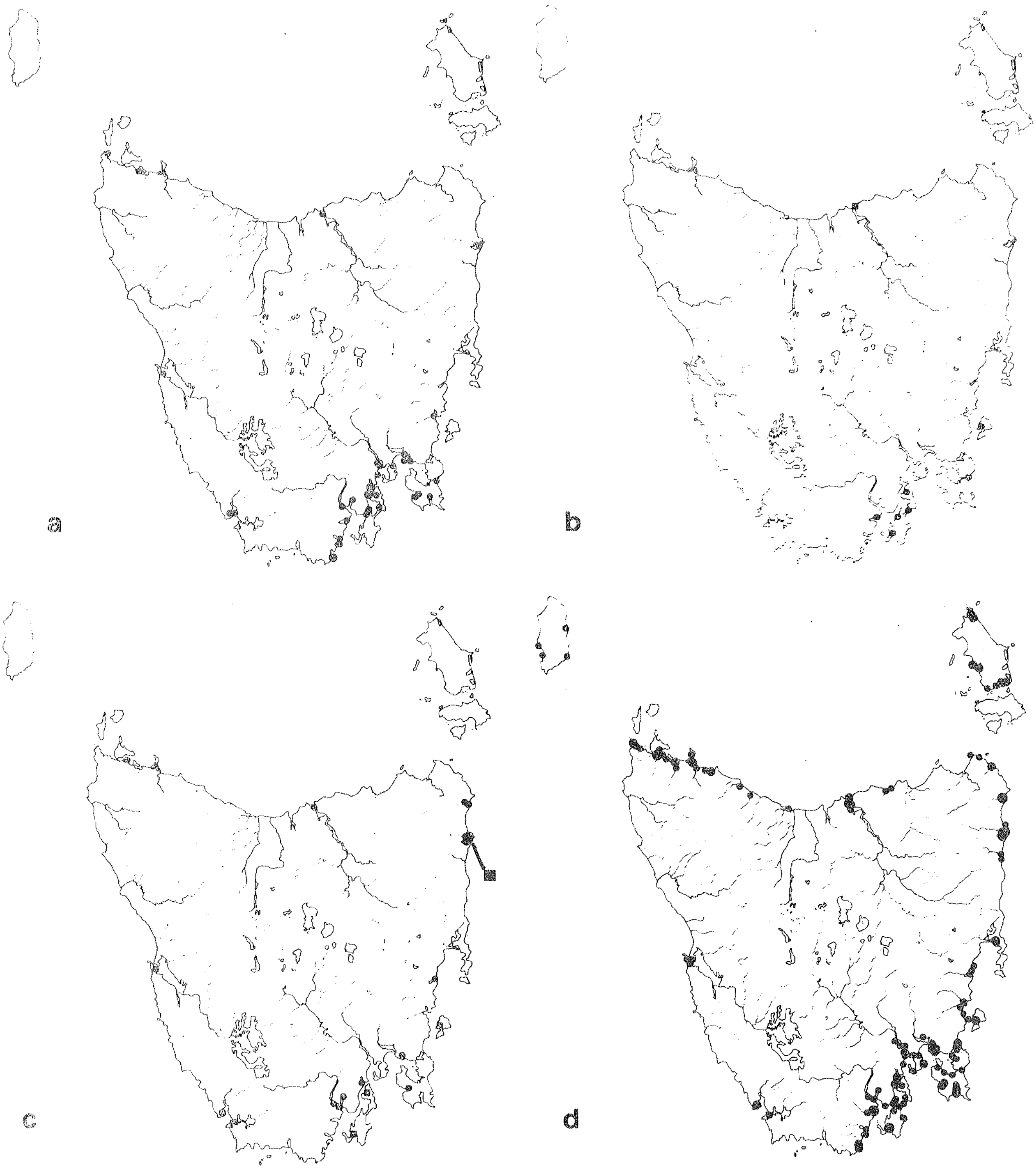
7:1:10. Distributions of (a) *Acanthopagrus butcheri* (●), *Girella tricuspidata* (▪) and *Atypichthys strigatus* (○) (overlap between *A. butcheri* and *G. tricuspidata*, ◆ and between *A. strigatus* and *G. tricuspidata*, ◉); (b) *Nannoperca australis* (●); (c) *Arripis trutta* (●); (d) *Brachionichthys hirsutus* (●).



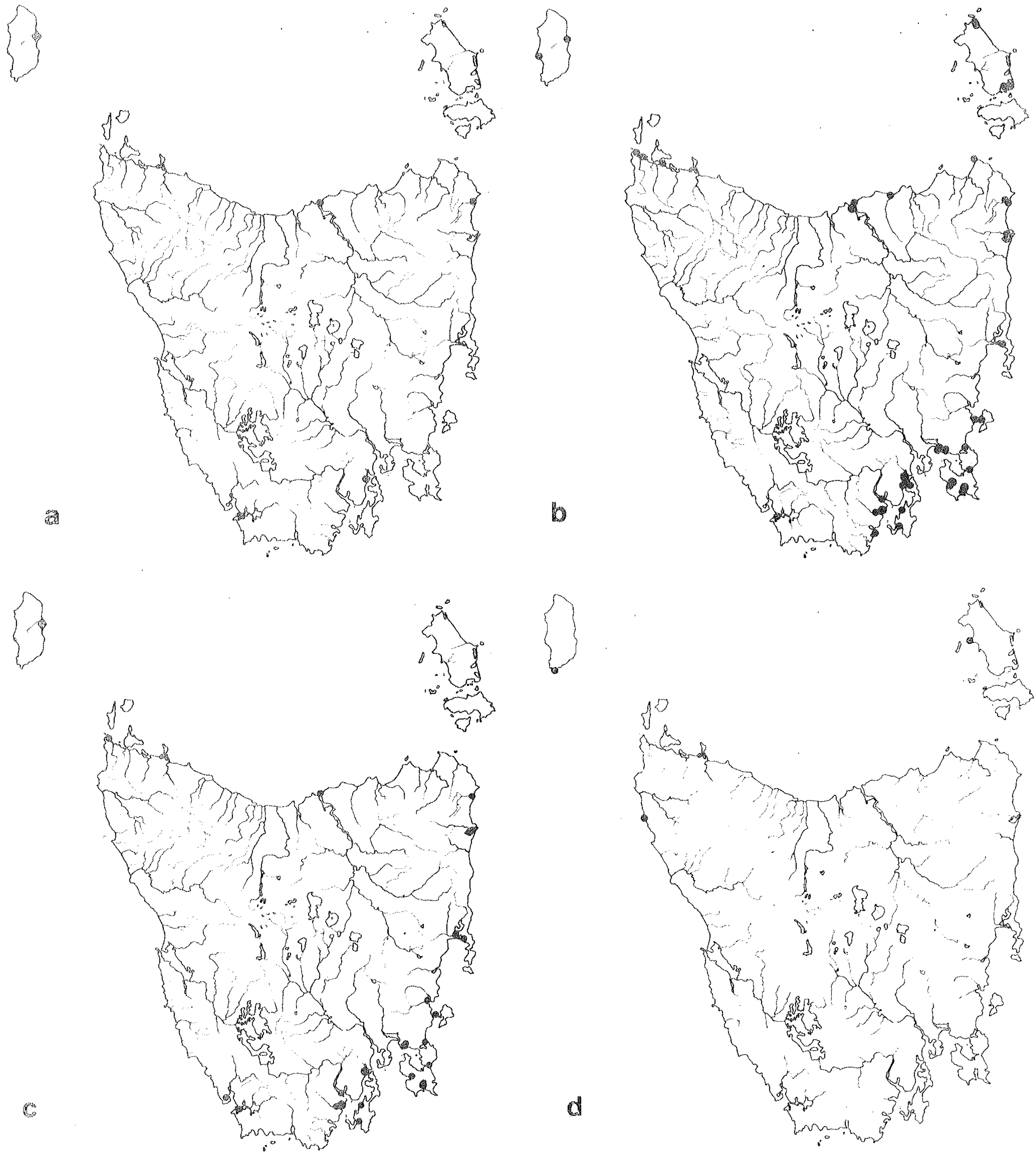
7:1:11. Distributions of (a) *Crapatalus arenarius* (●) and *C.sp.* (■) (overlap, ◆); (b) *Kathetostoma laeve* (●); (c) *Pseudaphritis urvillii* (●) and *Bovichthys variegatus* (■); (d) *Philypnodon grandiceps* (●).



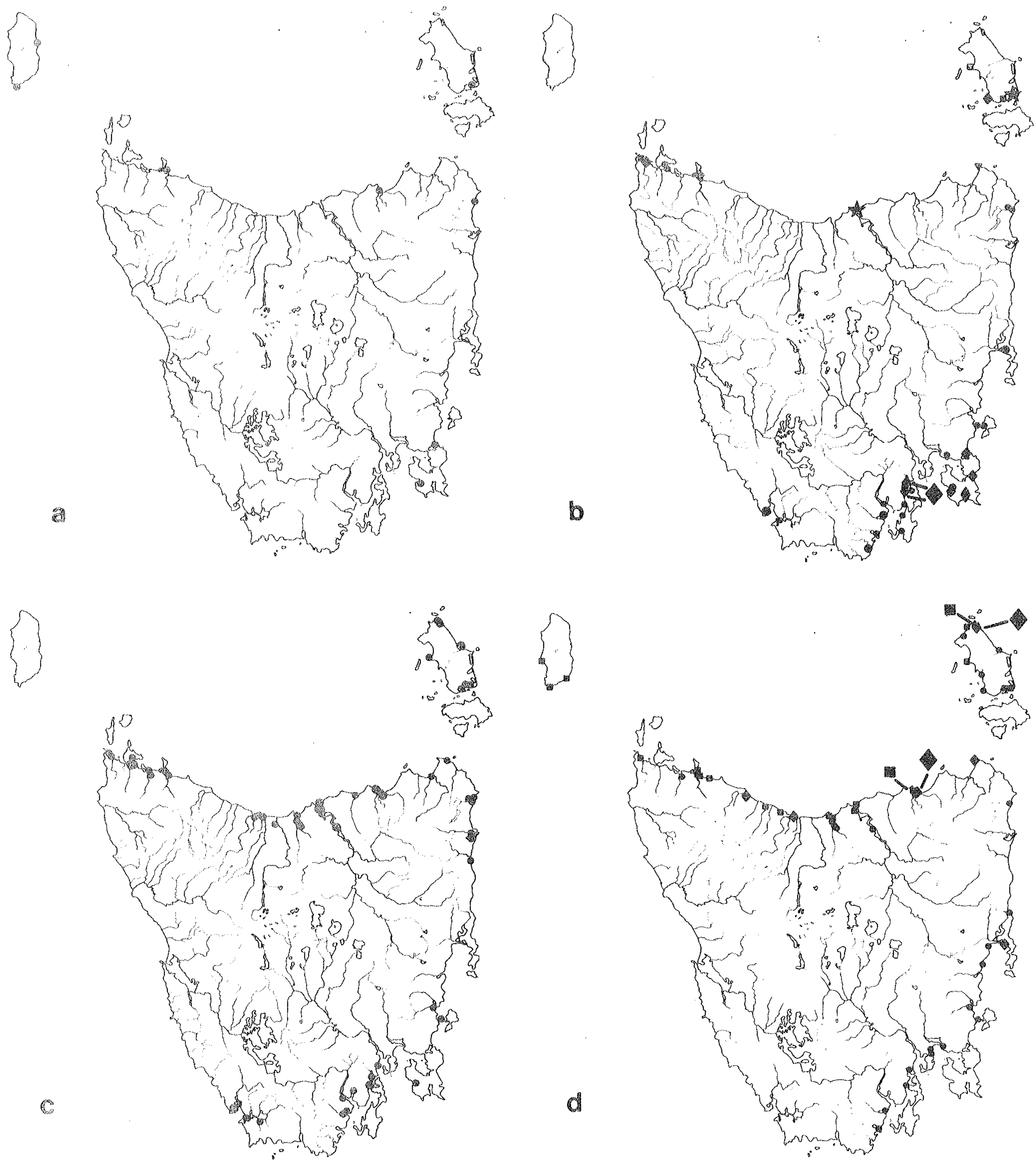
7:1:12. Distributions of (a) *Favonigobius tamarensis* (●) and *F. lateralis* (■) (overlap, ◆); (b) *Amoya bifrenatus* (●) and *A. frenatus* (■); (c) *Pseudogobius olorum* (●), *Callogobius mucosus* (■) and *Favonigobius sp.* (▼); (d) *Tasmanogobius sp3.* (●), *T. lordi* (■) and *T. sp.1* (□) (overlap between *T. sp.3* and *T. lordi*, ◆).



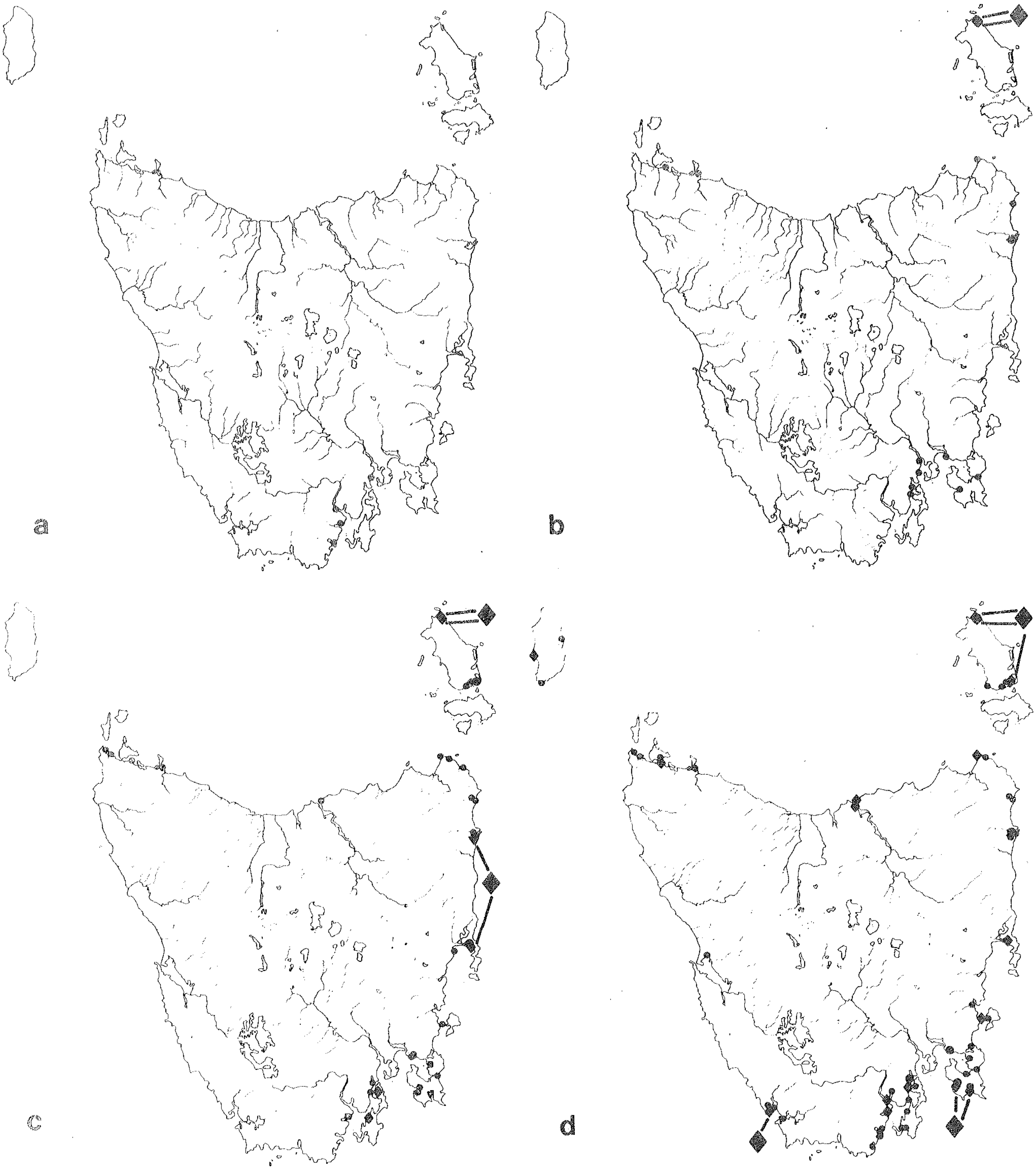
7:1:13. Distributions of (a) *Nesogobius hinsbyi* (●); (b) *N. sp.7* (●) and *N. sp.3* (■); (c) *N. sp.5* (●) and *N. pulchellus* (■); (d) *N. sp.2* (●).



7:1:14. Distributions of (a) *Heteroclinus macrophthalmus* (●), *H. wilsoni* (■) and overlap between *H. forsteri* and *H. heptaeolus* (◆); (b) *H. perspicillatus* (●); (c) *Cristiceps australis* (●) and overlap between *C. australis* and *C. argyropleura* (◆); (d) *Ophiclinus gracilis* (●).



7:1:15. Distributions of (a) *Pseudolabrus tetricus* (●); (b) *Neoodax balteatus* (●), *N. semifasciatus* (■) and *N. radiatus* (▼) (overlap between *N. balteatus* and *N. semifasciatus*, ◆ and between *N. balteatus, N. semifasciatus* and *N. radiatus*, ★); (c) *Torquigener glaber* (●); (d) *Contusus richei* (●) and *C.sp.* (■) (overlap, ◆).



7:1:16. Distributions of (a) *Aracana aurita* (●); (b) *Diodon nicthemerus* (●) and overlap between *D. nicthemerus* and *Dicotylichthys myersi* (◆); (c) *Meuschenia freycineti* (●), *Brachaluteres jacksonianus* (■) and *Eubalichthys gunnii* (▼) (overlap between *B. jacksonianus* and *M. freycineti*, ◆); (d) *Acanthaluteres spilomelanurus* (●) and overlap between *A. spilomelanurus* and *Penicipelta vittiger* (◆).

Appendix 7:2 : Similarity matrices (%) for centroid cluster analyses of coastal regions for: a. closed systems; b. bay estuaries/open lagoons; c. tidal rivers/creeks; d. sheltered beaches; and e. exposed beaches. Coastal regions follow those outlined in Section 4:3:4. (1, BF) Furneaux Group. (2, BW) North Coast. (3, BW) Western North Coast. (4, NW) Northern West Coast. (5, W) West Coast. (6, SW) South-West Coast. (7, SC) D'Entrecasteaux Channel. (8, SD) Derwent Estuary. (9, SE) South-East Bays. (10, SE) Peninsula. (11, E) East Coast. (12, E) Northern East Coast. (13, NE) North-East Coast. (14, BE) Eastern North Coast. (15, BT) Tamar River. (16, BK) King Island.

a

1	BF	-				
12	E	43.8	-			
7	SC	23.1	35.3	-		
10	SE	26.3	47.6	50.0	-	
16	BK	18.2	17.6	8.3	10.5	-
		1	12	7	10	16

Region Number

b

1	BF	-													
9	SE	33.3	-												
11	E	43.9	46.7	-											
12	E	48.2	45.7	55.8	-										
13	NE	48.1	48.8	62.5	64.6	-									
15	BT	38.3	42.6	42.1	39.0	43.6	-								
5	W	21.2	42.4	32.6	31.9	28.3	29.2	-							
8	SD	25.4	38.1	33.3	32.7	32.1	25.9	47.2	-						
6	SW	23.5	42.4	35.6	31.9	37.2	31.9	40.0	26.2	-					
7	SC	31.7	43.2	42.6	44.4	44.2	41.8	48.7	40.8	48.7	-				
2	BW	25.0	25.7	26.1	22.9	21.7	31.1	39.3	25.0	21.9	27.9	-			
3	BW	23.5	27.0	32.6	29.2	31.1	31.9	44.8	39.5	27.3	38.1	50.0	-		
14	BE	26.7	20.6	25.0	27.3	23.3	27.3	28.6	20.5	20.0	26.8	32.0	33.3	-	
16	BK	15.4	25.7	28.9	22.9	27.3	18.0	30.0	25.0	34.5	27.9	16.1	25.8	17.9	-
		1	9	11	12	13	15	5	8	6	7	2	3	14	16

Region Number

c

1	BF	-							
16	BK	30.8	-						
2	BW	29.2	30.4	-					
3	BW	38.9	41.2	65.2	-				
7	SC	26.9	28.0	48.4	48.1	-			
14	BE	23.5	17.6	36.0	40.0	33.3	-		
4	NW	18.8	28.6	33.3	30.0	25.9	15.8	-	
5	W	21.4	23.1	25.0	26.3	23.1	11.1	50.0	-
		1	16	2	3	7	14	4	5

Region Number

e

1	BF	-							
2	BW	16.7	-						
3	BW	27.8	57.1	-					
9	SE	21.1	57.1	52.9	-				
11	E	33.3	41.2	47.4	64.7	-			
4	NW	17.6	45.5	42.9	42.9	37.5	-		
16	BK	30.6	35.3	35.0	42.1	38.1	50.0	-	
10	SE	32.4	31.6	45.0	38.1	34.8	27.8	30.4	-
		1	2	3	9	11	4	16	10

Region Number

d

1	BF	-							
3	BW	40.8	-						
9	SE	37.5	48.9	-					
10	SE	42.5	50.0	56.8	-				
7	SC	30.0	47.6	49.1	47.3	-			
6	SW	36.4	36.4	39.4	41.2	35.3	-		
11	E	33.3	31.1	45.2	38.2	30.8	40.0	-	
16	BK	25.8	22.7	25.0	27.3	18.9	30.4	38.1	-
		1	3	9	10	7	6	11	16

Region Number

Legend to symbols used in Appendix 7:3

Source:

S - specimens sampled by author during study. Material is held at the research laboratory of the Tasmanian Fisheries Development Authority.

O - specimens donated or examined from other sources.

P - specimens identified from underwater photographs.

Q.V.M./T.M. code - Museum records, Queen Victoria Museum (Q.V.M.) and Tasmanian Museum (T.M.).

author (date) - liturature records.

Commonness:

R_T - rare in Tasmanian waters (known in this region from a few records).

R_E - rare in Tasmanian estuaries (known in estuaries from a few records but may be common in other habitats).

I_T - seldom present in Tasmanian waters (occurrence sporadic in this region).

I_M - marine species seldom present in estuaries (estuarine occurrence confined mainly to large systems).

I_E - migrants and estuarine and freshwater species seldom present in estuaries (occurrence in some estuaries only, or use estuaries only as a migratory route).

C_M - common marine species also occurring commonly in lower areas of large estuaries.

C_E - estuarine and freshwater species occurring commonly in some estuaries only (usually present only in large systems).

W - widespread in all estuarine types around Tasmania.

Habit:

S.F. - stenohaline freshwater.

E.F. - euryhaline freshwater.

E. - estuarine.

E.M. - euryhaline marine.

S.M. - stenohaline marine.

A. - anadromous.

C. - catadromous.

D. - diadromous.

Appendix 7:3 : Checklist of fishes recorded from Tasmanian estuaries. Source of records, commonness and status of species in estuaries are also provided.

			Source	Comm-onness	Habit
GEOTRIIDAE					
Geotria australis	Gray, 1851	Pouched Lamprey	S	IE	A
MORDACIIDAE					
Mordacia mordax	(Richardson, 1846)	Short-headed Lamprey	S	IE	A
HETERODONTIDAE					
Heterodontus portusjacksoni	(Meyer, 1793)	Port Jackson Shark	QVM 1976/5/66	IM	SM
HEXANCHIDAE					
Notorynchus cepedianus	(Peron, 1807)	Seven-gilled Shark	0	CE	EM
ORECTOLOBIDAE					
Parascyllium ferrugineum	McCulloch, 1911	Rusty Catshark	0	IM	SM
Parascyllium multimaculatum	Scott, 1935	Tasmanian Spotted Catshark	0	RE	SM
CETORHINIDAE					
Cetorhinus maximus	(Gunnerus, 1765)	Basking Shark	Scott (1976)	RT	SM
SCYLIORHINIDAE					
Cephaloscyllium laticeps	(Dumeril, 1853)	Draughtboard Shark	S	IM	EM
CARCHARHINIDAE					
Carcharhinus brachyurus	(Günther, 1870)	Bronze Whaler Shark	Scott (1977)	IM	SM
Galeorhinus australis	(Macleay, 1881)	School Shark	S	CE	EM
Mustelus antarcticus	Günther, 1870	Gummy Shark	S	CE	EM
SPHYRNIDAE					
Sphyrna zygaena	(Linnaeus, 1758)	Hammerhead Shark	Scott (1977)	RT	EM
SQUALIDAE					
Squalus megalops	(Macleay, 1881)	Spiked Dogfish	S	CM	EM
Squalus acanthias	Linnaeus, 1758	White-spotted Dogfish	S	CE	EM
PRISTIOPHORIDAE					
Pristiophorus nudipinnis	Günther, 1870	Southern Saw Shark	S	IM	SM
SQUATINIDAE					
Squatina australis	Regan, 1906	Angel Shark	Scott (1974a)	IM	SM
RHINOBATIDAE					
Trygonorhina guanerius	Whitley, 1932	Southern Fiddler	QVM 1980/5/27	RE	SM
TORPEDINIDAE					
Narcine tasmaniensis	Richardson, 1840	Tasmanian Numbfish	S	CE	EM

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
RAJIDAE					
Raja lemprieri	Richardson, 1845	Thornback Skate	S	CE	EM
Raja whitleyi	Iredale, 1938	Melbourne Skate	S	IM	SM
DASYATIDAE					
Dasyatis brevicaudatus	(Hutton, 1875)	Smooth Stingray	0	IM	SM
Dasyatis guileri	Last, 1979	Guiler's Stingray	0	RT	SM
UROLOPHIDAE					
Urolophus cruciatus	(Lacepede, 1804)	Banded Stingaree	S	CE	EM
Urolophus paucimaculatus	Dixon, 1969	Sparsely-spotted Stingaree	S	IM	SM
MYLIOBATIDAE					
Myliobatis australis	Macleay, 1881	Eagle Ray	S	IM	SM
CALLORHYNCHIDAE					
Callorhynchus milii	Bory de St Vincent, 1823	Elephant Fish	S	CM	EM
CLUPEIDAE					
Clupea bassensis	McCulloch, 1911	Sprat	S	IM	EM
DUSSUMIERIIDAE					
Spratelloides robustus	Ogilby, 1897	Blue Sprat	S	IM	SM
ENGRAULIDAE					
Engraulis australis	(White, 1790)	Australian Anchovy	S	CE	EM
ANGUILLIDAE					
Anguilla australis	Richardson, 1841	Short-finned Eel	S	W	C
Anguilla reinhardtii	Steindachner, 1867	Long-finned Eel	S	CE	C
CONGRIDAE					
Conger verreauxi	Kaup, 1856	Verreaux's Conger Eel	S	CM	EM
OPHICHTHIDAE					
Muraenichthys breviceps	Günther, 1876	Short-headed Worm Eel	S	CM	EM
Muraenichthys tasmaniensis	McCulloch, 1911	Tasmanian Worm Eel	Scott (1961)	IM	EM
Ophisurus serpens	(Linnaeus, 1758)	Serpent Eel	Scott (1963)	RT	EM
SALMONIDAE					
Salmo gairdnerii	Richardson, 1836	Rainbow Trout	0	IE	D
Salmo trutta	Linnaeus, 1758	Brown Trout	S	CE	D
RETROPINNIDAE					
Retropinna tasmanica	McCulloch, 1920	Tasmanian smelt	S	CE	E

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
PROTOTROCTIDAE					
Prototroctes maraena	Günther, 1864	Australian Grayling	S	IE	D
APLOCHITONIDAE					
Lovettia sealii	(Johnston, 1883)	Tasmanian Whitebait	S	CE	A
GALAXIIDAE					
Galaxias brevipinnis	Günther, 1866	Climbing Galaxias	S	IE	D
Galaxias cleaveri	Scott, 1934	Tasmanian Mudfish	Fulton (pers.com.)	IE	EF
Galaxias maculatus	(Jenyns, 1842)	Common Jollytail	S	W	D
Galaxias truttaceus	Cuvier, 1816	Spotted Mountain Trout	S	CE	D
GONORYNCHIDAE					
Gonorynchus greyi	(Richardson, 1845)	Beaked Salmon	S	IM	SM
PLOTOSIDAE					
Cnidoglanis macrocephalus	(Valenciennes, 1840)	Estuary Catfish	O	RT	E
AULOPODIDAE					
Aulopus purpurissatus	Richardson, 1843	Sergeant Baker	Scott (1942)	IT	SM
MORIDAE					
Pseudophycis bachus	(Bloch & Schneider, 1801)	Red Cod	S	W	EM
Pseudophycis barbatus	Günther, 1863	Bearded Rock Cod	P	IM	SM
MERLUCCIIDAE					
Macruronus novaezelandiae	(Hector, 1871)	Blue Grenadier	S	CM	EM
OPHIDIIDAE					
Genypterus blacodes	(Schneider, 1801)	Pink Ling	S	IM	SM
Genypterus sp.		Rockling	S	CM	EM
BRACHIONICHTHYIDAE					
Brachionichthys hirsutus	(Lacepède, 1804)	Spotted Handfish	S	CE	EM
SCOMBERESOCIDAE					
Scomberesox forsteri	Valenciennes, 1846	King Gar	Lord & Scott (1924)	RT	SM
EXOCOETIDAE					
Hirundichthys rondeletii	(Valenciennes, 1846)	Rondelet's Flying Fish	Scott (1934)	RE	SM
HEMIRAMPHIDAE					
Hyporhamphus melanochir	(Valenciennes, 1846)	South Australian Garfish	S	CM	SM
ATHERINIDAE					
Atherinosoma microstoma	(Günther, 1861)	Small-mounted Hardyhead	S	W	E
Atherinosoma presbyteroides	(Richardson, 1843)	Silverfish	S	W	EM
Atherinason esox	(Klunzinger, 1872)	Pike-headed Hardyhead	S	IM	SM
Atherinason hepsetoides	(Richardson, 1843)	Richardson's Hardyhead	S	CE	EM
Atherinason sp.		Short-headed Hardyhead	S	CE	EM

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
TRACHICHTHYIDAE					
Paratrachichthys trailii	(Hutton, 1875)	Sandpaper Fish	O	IM	SM
ZEIDAE					
Cyttus australis	(Richardson, 1843)	Silver Dory	S	IM	SM
MACRORHAMPHOSIDAE					
Macrorhamphosus scolopax	(Linnaeus, 1758)		TM D241	RE	SM
SYNGNATHIDAE					
Hippocampus abdominalis	Lesson, 1827	Big-bellied Sea Horse	S	CE	EM
Leptonotus costatus	Waite & Hale, 1921	Deep-bodied Pipefish	S	RT	SM
Leptonotus semistriatus	Kaup, 1853	Half-banded Pipefish	S	IM	SM
Lissocampus caudalis	Waite & Hale, 1921	Smooth Pipefish	Scott (1977)	RT	SM
Phyllipteryx taeniolatus	(Lacepede, 1804)	Common Sea Dragon	P	IM	SM
Solegnathus spinosissimus	(Günther, 1870)	Spiny Pipehorse	P	IM	EM
Stigmatopora argus	(Richardson, 1840)	Spotted Pipefish	S	CM	EM
Stigmatopora nigra	Kaup, 1853	Wide-bodied Pipefish	S	W	EM
Stipecampus cristatus	(McCulloch & Waite, 1918)	Ring-backed Pipefish	S	RE	SM
Syngnathus curtirostris	Castelnau, 1872	Pug-nosed Pipefish	S	IM	SM
Syngnathus phillipi	Lucas, 1891	Port Phillip Pipefish	S	CM	EM
Syngnathus poecilolaemus	Peters, 1869	Long-snouted Pipefish	S	IM	SM
Urocampus carinirostris	Castelnau, 1872	Hairy Pipefish	S	W	E
SCORPAENIDAE					
Glyptauchen panduratus	(Richardson, 1850)	Goblin Fish	QVM 1980/5/4	IM	SM
Gymnapistes marmoratus	(Cuvier, 1829)	Soldier Fish	S	W	EM
Helicolenus papillosus	(Bloch & Schneider, 1801)	Red Gurnard Perch	P	IM	SM
Neosebastes scorpaenoides	Guichenot, 1867	Common Gurnard Perch	S	CM	EM
Scorpaena ergastulorum	Richardson, 1842	Common Red Rock Cod	S	CM	EM
TRIGLIDAE					
Chelidonichthys kumu	(Lesson & Garnot, 1826)	Red Gurnard	S	IM	SM
Paratrigla papilio	(Cuvier , 1829)	Spiny Gurnard	S	CM	SM
Paratrigla vanessa	(Richardson, 1839)	Butterfly Gunard	S	IM	SM
Pterygotrigla polyommata	(Richardson, 1839)	Latchet	S	IM	SM
PATAECIDAE					
Aetapcus maculatus	(Günther, 1861)	Warty Prow Fish	P	IM	SM
Gnathanacanthus goetzeei	Bleeker, 1855	Red Velvet Fish	P	IM	SM
PLATYCEPHALIDAE					
Platycephalus bassensis	Cuvier, 1829	Sand Flathead	S	W	EM
Platycephalus castelnaui	Macleay, 1881	Castelnau's Flathead	S	CE	EM
Platycephalus laevigatus	Cuvier, 1829	Rock Flathead	S	IM	SM
Neoplatycephalus richardsoni	(Castelnau, 1872)	Tiger Flathead	O	RE	SM
PEGASIDAE					
Acanthopegasus lancifer	(Kaup, 1861)	Sea moth	S	IM	EM
PERCICHTHYIDAE					
Macquaria colonorum	(Günther, 1863)	Estuarine Perch	Johnston (1891)	RT	E

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
SERRANIDAE					
Caesioperca lepidoptera	(Bloch & Schneider, 1801)	Butterfly Perch	P	CM	EM
Caesioperca rasor	(Richardson, 1839)	Barber Perch	P	CM	EM
PLESIOPIDAE					
Trachinops caudimaculatus	McCoy, 1890	Blotch-tailed Trachinops	S	CM	SM
KUHLIIDAE					
Nannoperca australis	Günther, 1861	Southern Pigmy Perch	S	IE	EF
DINOLESTIDAE					
Dinolestes lewini	(Griffith, 1834)	Long-finned Pike	S	CM	SM
APOGONIDAE					
Siphamia cephalotes	Castelnau, 1875	Wood's Siphon Fish	S	RT	SM
Apogon conspersus	Klunzinger, 1872	Southern Cardinal Fish	S	RE	SM
SILLAGINIDAE					
Sillaginodes punctatus	(Cuvier, 1829)	Spotted Whiting	O	RE	EM
Sillago bassensis	Cuvier, 1829	School Whiting	S	CM	EM
POMATOMIDAE					
Pomatomus saltator	Linnaeus, 1766	Tailor	S	IM	SM
CARANGIDAE					
Caranx georgianus	Valenciennes, 1833	Silver Trevally	S	CM	EM
Seriola lalandi	Valenciennes, 1833	Yellowtail Kingfish	O	IM	SM
Trachurus declivis	(Jenyns, 1841)	Jack Mackerel	S	CM	EM
ARRIPIDAE					
Arripis trutta esper	Whitley, 1951	Western Australian salmon	S	IM	EM
Arripis trutta marginata	(Cuvier, 1828)	Eastern Australian salmon	S	W	EM
GERREIDAE					
Parequula melbournensis	(Castelnau, 1872)	Silverbelly	Scott (1964)	RE	SM
SPARIDAE					
Acanthopagrus butcheri	(Munro, 1949)	Black Bream	S	CE	E
Chrysophrys auratus	(Bloch & Schneider, 1801)	Snapper	O	IT	EM
SCIAENIDAE					
Argyrosomus hololepidotus	(Lacepede, 1802)	Mulloway	Johnston (1883)	RT	EM
MULLIDAE					
Upeneichthys lineatus	(Bloch & Schneider, 1801)	Blue-spotted Goatfish	S	IE	EM
Upeneus tragula	Richardson, 1846	Bar-tailed Goatfish	S	RT	SM
PEMPHERIDAE					
Pempheris multiradiatus	Klunzinger, 1879	Common Bullseye	P	CM	EM

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
SCORPIDAE					
Atypichthys strigatus	(Günther, 1860)	Mado Sweep	S	IT	SM
Scorpis aequipinnis	Richardson, 1848	Sea Sweep	P	IM	SM
Scorpis lineolatus	Kner, 1865	Sweep	P	IM	SM
KYPHOSIDAE					
Girella elevata	Macleay, 1881	Black Drummer	S	IT	SM
Girella tricuspidata	(Quoy & Gaimard, 1824)	Luderick	S	CE	EM
Melambaphes zebra	(Richardson, 1846)	Zebra Fish	P	IM	SM
ENOPLOSIDAE					
Enoplosus armatus	(White, 1790)	Old Wife	S	IM	EM
PENTACEROTIDAE					
Pentaceropsis recurvirostris	(Richardson, 1845)	Long-snouted Boarfish	P	IM	SM
POMACENTRIDAE					
Parma microlepis	Günther, 1862	White Ear	P	IM	SM
Parma victoriae	(Günther, 1863)	Scaly Fin	P	IM	SM
APLODACTYLIDAE					
Dactylosargus arctidens	(Richardson, 1839)	Marblefish	Lord & Scott(1924)	IM	SM
CHEILODACTYLIDAE					
Cheilodactylus nigripes	Richardson, 1850	Magpie Perch	P	CM	SM
Cheilodactylus spectabilis	(Hutton, 1872)	Banded Morwong	P	IM	SM
Dactylophora nigricans	(Richardson, 1850)	Dusky Morwong	P	IT	SM
Nemadactylus macropterus	(Bloch & Schneider,1801)	Morwong	S	CM	EM
LATRIDAE					
Latridopsis forsteri	(Castelnau, 1872)	Bastard Trumpeter	S	CM	EM
Latris lineata	(Bloch & Schneider,1801)	Striped Trumpeter	P	RE	SM
Mendosoma allporti	Johnston, 1881	Real Bastard Trumpeter	Johnston (1881)	RE	SM
MULGILIDAE					
Aldrichetta forsteri	(Valenciennes, 1836)	Yellow-eyed Mullet	S	W	EM
Mugil cephalus	Linnaeus, 1758	Sea Mullet	S	IM	EM
Myxus elongatus	Günther, 1861	Sand Mullet	S	IM	EM
SPHYRAENIDAE					
Sphyraena novaehollandiae	Günther, 1860	Short-finned Pike	C	IM	SM
LABRIDAE					
Dotalabrus aurantiacus	(Castelnau, 1872)	Castelnau's Wrasse	P	IM	SM
Pictilabrus laticlavius	(Richardson, 1839)	Senator Fish	P	CM	SM
Pseudolabrus fucicola	(Richardson, 1840)	Purple Wrasse	P	CM	SM
Pseudolabrus psittaculus	(Richardson, 1840)	Rosy Wrasse	P	IM	SM
Pseudolabrus tetricus	(Richardson, 1840)	Blue-throated Wrasse	S	IM	SM
ODACIDAE					
Heteroscarus acroptilus	(Richardson, 1846)	Rainbow Fish	O	RE	SM
Neoodax balteatus	(Valenciennes, 1839)	Little Rock Whiting	S	W	EM
Neoodax beddomei	(Johnston, 1885)	Pigmy Rock Whiting	P	IM	SM
Neoodax radiatus	(Quoy & Gaimard, 1835)	Long-rayed Rock Whiting	S	IT	SM
Neoodax semifasciatus	(Valenciennes, 1840)	Blue Rock Whiting	S	IM	SM
Olisthops cyanomelas	Richardson, 1850	Herring Cale	O	IM	SM

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
URANOSCOPIDAE					
Kathetostoma laeve	(Bloch & Schneider,1801)	Common Stargazer	S	IM	SM
LEPTOSCOPIDAE					
Crapatalus arenarius	McCulloch, 1915	Common Sandfish	S	IM	SM
Crapatalus sp.		Pink Sandfish	S	IM	SM
BOVICHTHYIDAE					
Bovichthys variegatus	(Richardson, 1846)	Dragonet	S	CM	EM
Pseudaphritis urvillii	(Cuvier & Valenciennes,1831)	Congolli	S	W	E
TRIPTERYGIIDAE					
Brachynectes fasciatus	Scott, 1957	Barred Threefin	Scott (1977)	IT	SM
Forsterygion gymnotum	Scott, 1977	Bare-backed Threefin	S	CE	EM
Forsterygion multiradiatum	Scott, 1977	Many-rayed Threefin	S	CE	EM
Gillias macleayana	(Lucas, 1891)	Macleay's Threefin	Scott (1938)	I	SM
Tripterygion whitleyi	Scott, 1977	Whitley's Threefin	Scott (1977)	RT	EM
CLINIDAE					
Cristiceps argyropleura	Kner, 1865	Silver-sided Weedfish	S	RT	SM
Cristiceps australis	Valenciennes, 1836	Crested Weedfish	S	W	EM
Heteroclinus adelaidae	Castelnau, 1872	Adelaide Weedfish	S	IM	SM
Heteroclinus forsteri	(Castelnau, 1872)	Forster's Weedfish	S	IM	SM
Heteroclinus heptaeolus	(Ogilby, 1885)	Ogilby's Weedfish	S	IM	SM
Heteroclinus johnstoni	(Saville-Kent, 1886)	Johnston's Weedfish	S	IM	SM
Heteroclinus macrophthalmus	Hoese, 1976	Large-eyed Weedfish	S	IM	SM
Heteroclinus perspicillatus	Valenciennes, 1836)	Common Weedfish	S	CM	EM
Heteroclinus wilsoni	(Lucas, 1890)	Wilson's Weedfish	S	IM	SM
Ophiclinus gracilis	Waite, 1906	Black-backed snake Blenny	S	IM	SM
BLENNIDAE					
Pictiblennius tasmanianus	(Richardson, 1849)	Tasmanian Blenny	S	W	EM
ELEOTRIDAE					
Philypnodon grandiceps	(Krefft, 1864)	Big-headed Gudgeon	S	RT	EF
GOBIIDAE					
Amoya bifrenatus	(Kner, 1865)	Bridled Goby	S	CE	E
Callogobius mucosus	(Günther, 1872)	Sculptured Goby	S	IM	SM
Favonigobius tamarensis	(Johnston, 1883)	Tamar Goby	S	W	E
Favonigobius lateralis	(Macleay, 1881)	Long-finned Goby	S	CE	EM
Favonigobius sp.		King Island Goby	S	RT	EF
Nesogobius hinsbyi	(Johnston, 1903)	Orange-spotted Goby	S	IM	SM
Nesogobius pulchellus	(Castelnau, 1872)	Castelnau's Goby	S	IM	SM
Nesogobius sp. 2		Girdled Goby	S	W	EM
Nesogobius sp. 3		Rotund Goby	S	W	EM
Nesogobius sp. 5		Twin-barred Goby	S	CE	EM
Pseudogobius olorum	(Sauvage, 1880)	Blue-spot Goby	S	W	E
Tasmanogobius lordi	Scott, 1935	Lord's Goby	S	CE	E
Tasmanogobius sp. 3		Lagoon Goby	S	W	E
GEMPYLIDAE					
Thyrsites atun	(Euphrasen, 1791)	Snoek	S	IM	SM
TRICHIURIDAE					
Lepidopus caudatus	(Euphrasen, 1788)	Southern Frost Fish	Scott (1960)	RE	SM

Appendix 7:3 (Continued)

			Source	Comm-onness	Habit
SCOMBRIDAE					
Auxis thazard	(Lacepede, 1801)	Frigate Mackerel	TM D70/536	RE	SM
Gasterochisma melampus	Richardson, 1845	Butterfly Mackerel	Johnston (1883)	RE	SM
Katsuwonus pelamis	(Linnaeus, 1758)	Skipjack Tuna	QVM 1974/5/107	RE	SM
Scomber australasicus	Cuvier, 1832	Australian Mackerel	O	RE	SM
Thunnus maccoyii	(Castelnau, 1872)	Bluefin tuna	Johnston (1883)	RE	SM
CENTROLOPHIDAE					
Schedophilus huttoni	Waite, 1910	Hutton's Trevalla	Scott (1978)	RT	SM
Seriolella brama	(Günther, 1860)	Warehou	S	CM	EM
Seriolella punctata	(Bloch & Schneider, 1801)	Spotted Trevalla	S	IM	EM
GOBIESOCIDAE					
Aspasmogaster tasmaniensis	(Günther, 1861)	Tasmanian Clingfish	Scott (1936)	IM	SM
Cochleoceps spatula	(Günther, 1861)	Broad-headed Clingfish	Scott (1936)	IM	SM
Alabes dorsalis	(Richardson, 1848)	Red-banded Shore Eel	S	CM	EM
CALLIONYMIDAE					
Callionymus calauropomus	Richardson, 1844	Common Stinkfish	S	IM	SM
Callionymus papilio	Günther, 1864	Painted Stinkfish	S	IM	SM
BOTHIDAE					
Arnoglossus bassensis	Norman, 1926	Bass Strait Flounder	S	IM	EM
PLEURONECTIDAE					
Ammotretis liturata	(Richardson, 1843)	Spotted Flounder	S	IM	SM
Ammotretis rostratus	Günther, 1862	Long-snouted Flounder	S	W	EM
Rhombosolea tapirina	Günther, 1862	Greenback Flounder	S	W	EM
Taratretis derwentensis	Last, 1978	Derwent Flounder	S	W	EM
MONACANTHIDAE					
Acanthaluteres spilomelanurus	(Quoy & Gaimard, 1824)	Bridled Leatherjacket	S	W	EM
Brachaluteres jacksonianus	(Quoy & Gaimard, 1824)	Pigmy Leatherjacket	S	CE	EM
Eubalichthys gunnii	(Günther, 1870)	Velvet Leatherjacket	P	IM	SM
Meuschenia australis	(Donovan, 1824)	Brown-striped Leatherjacket	P	IM	SM
Meuschenia freycineti	(Quoy & Gaimard, 1824)	Six-spined Leatherjacket	S	W	EM
Meuschenia hippocrepis	(Quoy & Gaimard, 1824)	Horseshoe Leatherjacket	P	IM	SM
Penicipelta vittiger	(Castelnau, 1873)	Toothbrush Leatherjacket	S	CM	EM
OSTRACIONTIDAE					
Aracana aurita	(Shaw, 1798)	Shaw's Cowfish	S	CM	EM
Aracana ornata	(Gray, 1838)	Ornate Cowfish	O	IM	SM
TETRAODONTIDAE					
Contusus richei	(Freminville, 1813)	Barred Toadfish	S	IM	EM
Contusus sp.		Prickly Toadfish	S	IM	SM
Torquigener glaber	(Freminville, 1813)	Smooth Toadfish	S	W	EM
DIODONTIDAE					
Dicotylichthys myersi	Ogilby, 1910	Myer's Porcupinefish	S	RT	SM
Diodon nicthemerus	Cuvier, 1818	Globefish	S	CM	EM
MOLIDAE					
Mola ramsayi	Giglioli, 1883	Short Sunfish	Scott 1969b	RE	SM

4.

RELEVANT PUBLICATIONS

PUBLICATIONS

1. (1978). A new genus and species of flounder (F. Pleuronectidae) with notes on other Tasmanian species. *Pap. Proc. R. Soc. Tasm.* *112*, 21-8.

2. (1979) A new species of stingray (F. Dasyatidae) with a key to the Australian species. *Pap. Proc. R. Soc. Tasm. 115*, 169-76.

3. (1980) Recent records of the Australian grayling *Prototroctes maraena* Gunther (Pisces : Prototroctidae) with notes on its distribution. *Aust. Zool. 20*, 419-31

4. (1981) New locality records and preliminary information on demersal fish faunal assemblages in Tasmanian waters. *Pap. Proc. R. Soc. Tasm. 115*, 189-209.

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